PAPERS

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MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

XXIX (1943)

PART II: ZOOLOGY

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PART II: ZOOLOGY

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PAPERS OF THE MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

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VOLUME XXIX (1943)
PART II: ZOOLOGY

"Pusilla res mundus est nisi in illo
quod quaerat omnis mundus habeat."
— SENECA, *Naturales Quaestiones*

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ZOOLOGY

GEOGRAPHICAL VARIATION IN THE BLACK VULTURE

PIERCE BRODKORB

THE black vulture, *Coragyps atratus* (Bechstein), has a wide distribution, from the southeastern United States south to Argentina and Chile. Within this immense area size is the only character that is known to vary geographically. The most significant measurement is that of the wing. Measurements of tail and bill show the same trends as the wing, but to a less degree.

HISTORY

J. A. Allen (1905, p. 275) was the first author to suggest the geographic variability of the black vulture. He stated that South American birds were smaller than those of North America. Almost simultaneously Hellmayr (1906, p. 567) reached the conclusion that South American birds were separable subspecifically from those of North America. Unfortunately neither author published measurements to substantiate the claim to distinctness of the South American bird.

In recent years there has been little agreement among ornithologists on the advisability of recognizing a southern subspecies of this vulture. Some, notably Todd and Carriker (1922, p. 142) and Friedmann (1933, p. 187), have held that the differences are too inconstant for taxonomic separation. Others (Swann, 1924–1930, pp. 7–10; Chapman, 1926, p. 217; Dickey and van Rossem, 1938, p. 97) have accepted the division into a northern and a southern race. It has even been suggested (Wetmore, 1926, p. 91; Peters, 1929, p. 415; Aldrich, 1937, p. 38) that three subspecies instead of two may be involved.

MATERIAL

There have been used in the present study forty-four specimens from various parts of the range of the black vulture. This number, though greater than that available to previous investigators, was

thought to be not entirely adequate, since individuals in certain stages of molt had to be discarded. I have therefore incorporated published measurements of individual birds when these could be segregated by locality. Thus wing measurements of five were taken from Aldrich, four from Wetmore, three from Chapman, three from Swann, and one each from Dickey and van Rossem and from Salvin and Godman (1897–1904, p. 133).

SEXUAL VARIATION

According to Aldrich, sexual variation in size is insignificant in the black vulture. My material supports this statement; the wings of birds from the United States, for example, measure 418–448 mm. in six males, 417–443 mm. in five females. In samples from other localities sometimes one sex, sometimes the other, happens to be the larger. I have therefore combined the measurements of both sexes, since this permits the inclusion of specimens whose sex was not recorded.

GEOGRAPHIC VARIATION

When the wing measurements of vultures from North America were compared with those of South American birds, both lots were found to show about the same limits of variation. In birds from Panama northward the wing measured 381–454 mm. Among South American specimens the variation was 391–453 mm. Friedmann found 80 per cent of his specimens to fall within the range in wing length shown by birds of both continents. Obviously no separation can be made between North American birds as a whole on the one hand and South American birds as a whole on the other.

A different division was then made. The first group contained United States birds. The second lot consisted of specimens from tropical America, from Mexico south to about the Tropic of Capricorn. The third category was composed of individuals from the Temperate Zone of South America. This grouping brought out the fact that the vultures from the tropical area are small, while those from the temperate regions to north and south are large (Table I).

In order to test the significance of the geographic differences in wing length the figures were treated statistically by the graphic method recently devised by Hubbs and Perlmutter (1942). The

TABLE I

VARIATION IN WING LENGTH IN THE BLACK VULTURE

Locality	No.	Wing length in millimeters																		
		Mean	Min.	Max.	380–383	384–387	388–391	392–395	396–399	400–403	404–407	408–411	412–415	416–419	420–423	424–427	428–431	432–435	436–439	440–443	444–447	448–451	452–455
United States...	18	431.4	415	454	0	0	0	0	0	0	0	0	2	2	1	2	2	3	1	1	2	2	1
Tropical America	20	403.5	381	415	1	0	2	2	1	2	4	5	3	0	0	0	0	0	0	0	0	0	0
Temperate South America.....	16	430.9	418	453	0	0	0	0	0	0	0	0	0	2	2	1	4	5	0	0	0	0	2

thin vertical line (Fig. 1) shows the range of variation in the sample. The solid vertical bar gives one standard deviation on either side of the mean, which is indicated by the cross bar. The hollow rectangle represents twice the standard error on either side of the mean.

This method seems particularly adapted to taxonomic studies. In a normal curve 84 per cent of the specimens will fall within the range indicated by the solid vertical bar, a percentage that approximates the degree of differentiation usually accepted as the minimum for subspecific separation.

A significant difference between two populations is regarded as demonstrated if the gap between two rectangles exceeds 10 per cent of the length of the shorter rectangle. In Figure 1 the gap between the rectangle representing the Tropical Zone population and the rectangles representing both the North Temperate and the South Temperate Zone populations amounts to over 200 per cent of the length of the short rectangle. The difference in wing length between Tropical and Temperate Zone birds is thus taxonomically significant.

The length of the rectangle representing the South Temperate Zone birds is contained wholly within the height of the rectangle representing the North Temperate Zone birds. Thus no significance is to be attributed to a difference between the means of the two samples.

NOMENCLATURE OF THE TEMPERATE ZONE RACE

Although it is contrary to the usual theory for the range of one subspecies to consist of two separate parts interrupted by the range of another subspecies, I can see no justification for applying different names to the two Temperate Zone populations of black vultures. I therefore propose to treat them as the same subspecies. The proper

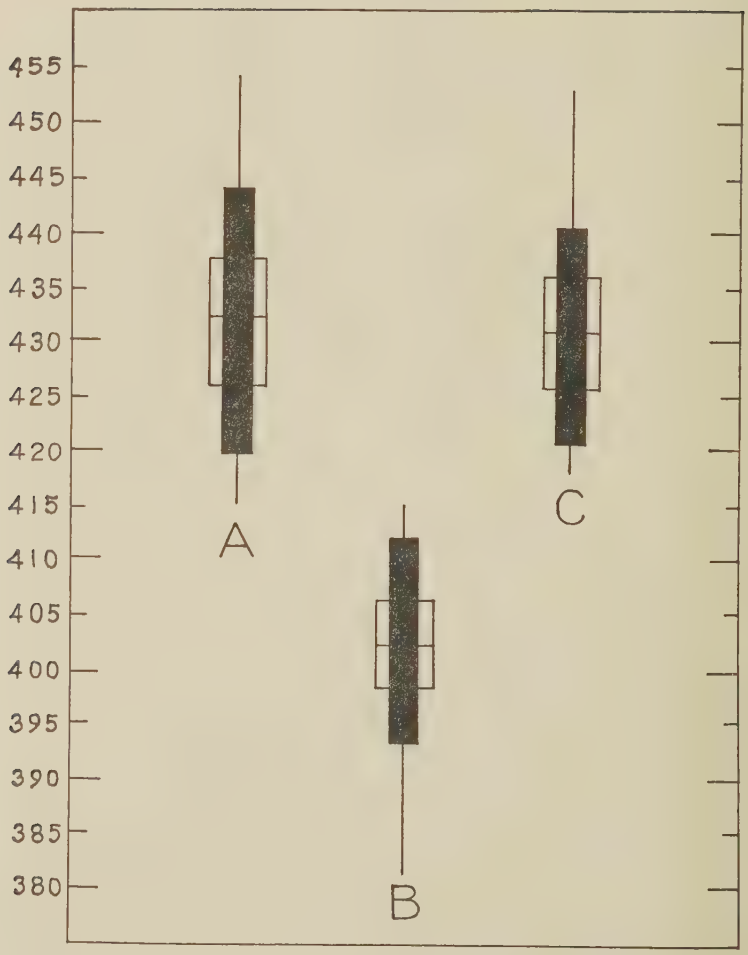

FIG. 1. Variation in wing length (mm.) in the black vulture, *Coragyps atratus*. *A*, United States (18 specimens); *B*, tropical America (20 specimens); *C*, temperate South America (16 specimens)

name for this form is *Coragyps atratus atratus* (Bechstein), based upon a bird from Florida.

The name *Cathartes foetens* Lichtenstein is a synonym of *C. atratus*. Lichtenstein's name, currently employed for a South American race, was founded on Azara's description of a bird from Paraguay. The small tropical race occurs only in the northwestern corner of the Chaco, beyond the area worked by Azara. Thirteen specimens from the remaining parts of the republic have wing measurements of 418–453 mm., and thus belong with *C. a. atratus*. In order to avoid any future confusion I restrict the type locality of *Cathartes foetens* to Asunción, Paraguay.

The possibility remains, of course, that future studies may disclose some overlooked difference between the northern and the southern colonies of Temperate Zone birds. In that case the name *foetens* would be available for the southern birds.

NOMENCLATURE OF THE TROPICAL ZONE RACE

As has already been demonstrated, the name *foetens* cannot be used for this subspecies. The first available name is *Coragyps atratus brasiliensis* (Bonaparte). Bonaparte described his bird as being smaller than the North American form, so that the applicability of his name can scarcely be questioned. He gave its distribution as South America and the Antilles. The Antillean locality is of course erroneous, and Swann restricted the type locality to "S. Brazil." A further restriction may be necessary, for although a specimen from Fazenda Miranda, Matto Grosso, belongs to the race *C. a. brasiliensis*, it seems likely that *C. a. atratus* will prove to be the subspecies of the southernmost states of Brazil.

POSSIBLE MIGRATION OF TEMPERATE ZONE BIRDS

There is some evidence which suggests that the Temperate Zone birds of both hemispheres are partially migratory. Five Mexican specimens, from localities from Sonora to Chiapas, including all the birds taken during the breeding season, are of the subspecies *C. a. brasiliensis*, with wings measuring 388 409 mm. Four specimens shot during September and March at Acacoyagua and Unión Juárez, Chiapas, are as big as others from the United States. Their wings measure 418–430 mm. These large nonbreeding black vultures from Mexico are interpreted as migrant individuals of *C. a. atratus*.

Nine black vultures from the Chaco west of Puerto Casado, Paraguay, some of which were collected during the breeding season, likewise belong to *C. a. brasiliensis*, since their wing measurements are 391–414 mm. Two others, taken in the winter months of February and May, measure 422 and 424 mm. They are considered migrants of *C. a. atratus* from temperate South America.

The turkey vulture, *Cathartes aura*, a species with which the present one often associates, is known to be partially migratory in the northern part of its range. It will be desirable to investigate further the possibility that the black vulture is also migratory.

EVOLUTION

It is interesting, though perhaps not very profitable, to speculate whether subspeciation in the black vulture took place in the center of the range of the species or whether the character of large size arose as an independent parallel mutation at the northern and southern ends of its range. Subspeciation is generally understood to occur at the periphery of the range of another form. There are, however, a few known exceptions, and a case in point is that of the cinnamon teal, *Anas cyanoptera*. This duck occurs from the western United States to Argentina. Within this area its characters are constant, except at Lake Titicaca, in the Andes of Peru. A local race, differentiated by larger size, inhabits that lake. Its distribution is so restricted that there can be little doubt that it originated there as a local mutation. Here is an example of subspeciation occurring near the center of the range of another form.

Argument that the small central form of black vulture was derived from the large end form could be made on paleontological grounds. Besides the modern bird in its two subspecies, the genus *Coragyps* contains a Pleistocene form from California and nearby areas. The Pleistocene bird, *Coragyps occidentalis* (L. H. Miller), had a wing even longer than that of *C. a. atratus*. Its known habitat lay largely beyond that of the modern bird. There is thus perhaps a trend, progressive both geographically and in point of time, from larger to smaller size.

University of Michigan

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EGG PRODUCTION OF THE NORTHERN PIKE, *ESOX LUCIUS* L., AND THE PERCENTAGE SURVIVAL OF EGGS AND YOUNG ON THE SPAWNING GROUNDS*

WILLIAM F. CARBINE

IN 1937 the writer started an investigation of the life history of the northern pike. The aim was to devise procedures for the management of this important game fish. Particular attention was paid to egg production and to the survival of the young from the time of hatching until the time when they leave the spawning grounds since little information was available on these phases of pike life history.

The work was begun in southern Michigan, but most of the field observations were made from 1939 to 1942 at Houghton Lake, the largest inland lake in Michigan and one of the most productive. Some of the results have already been published (Carbine, 1942).

EGG PRODUCTION

Materials and Methods

During 1939, 1940, and 1942 the writer and various staff members of the Institute for Fisheries Research secured at Houghton Lake thirty specimens of northern pike (Table I) for the making of egg counts. Some were caught during January and February by ice fishermen, but the data were gathered by the fishery investigators. A larger number were taken at random during the spawning run, from the weirs that were installed in ditches connected with the North Bay of Houghton Lake at Peterson's resort (Carbine, 1942). With the exception of two fish that were stripped at the time of capture only fish that were "green" (with egg sacs intact) were saved for samples.

Shortly after its capture each fish was weighed to the nearest gram or ounce, depending upon the size of the fish. Standard and

* Contribution from the Institute for Fisheries Research of the Michigan Department of Conservation.

TABLE I

DATA ON COLLECTION, SIZE, CONDITION, AND NUMBER OF EGGS FOR THIRTY NORTHERN PIKE COLLECTED AT HOUGHTON LAKE *

Counts made by C. B. Obrecht, W. F. Carbine, George N. Washburn and John T. Greenbank

Date collected	Standard length (millimeters)	Total length (inches)	Weight (ounces)	K	Number of eggs	Counted by
4–2–42	338	15.7	11.0 †	0.808	7,691	Carbine
3–29–42	370	17.0	16.0 †	0.896	13,309	"
4–15–39	443	20.3	34.0	1.109	28,871 ‡	Obrecht
2–25–39	446	20.6	26.0	0.831	16,898	"
4–15–39	455	20.7	33.0	0.994	22,966 ‡	"
2–25–39	450	20.7	34.0	1.058	24,030	"
4–22–39	452	20.7	33.5	1.029	25,982	"
4–18–39	458	20.9	31.5	0.930	25,760	"
4–18–39	460	21.0	33.0	0.962	21,086	Carbine
4–21–39	468	21.4	39.0	1.079	27,700	Obrecht
3–27–42	460	21.6	44.0	1.281	33,168	Carbine
4–21–39	475	21.7	33.5	0.886	19,418	Obrecht
4–21–39	490	22.3	39.0	0.940	12,599	"
4–21–39	485	22.3	39.5	0.982	27,550	Washburn
4–16–39	510	23.6	44.0	0.940	23,920	"
4–23–39	512	23.6	48.0	1.014	33,342	Obrecht
2–25–39	525	23.6	50.0	0.980	36,484	"
2–23–39	540	24.5	52.0	0.936	41,116	"
2–4–39	540	25.0	44.0	0.792	19,808	Carbine
2–26–39	559	25.4	52.0	0.844	47,289	Obrecht
4–17–39	570	25.9	56.0	0.857	38,756	"
2–25–39	566	26.0	54.0	0.844	29,945	"
4–13–39	571	26.0	60.0	0.914	37,332	Carbine
4–17–42 §	584	26.1	64.0 †	0.911	43,170	Greenbank and Carbine
2–25–39	578	26.2	60.0	0.881	38,989	Obrecht
4–18–39	578	26.2	70.0	1.027	44,902	"
1–28–43 ‖	600	27.1	67.0	0.879	36,812	Carbine
1–28–39	600	27.2	68.0	0.893	54,085	Greenbank
2–23–39	638	28.4	88.0	0.961	35,754	Obrecht
4–23–39	775	35.0	170.5	1.038	97,273	"
Averages	516.5	23.6	49.8	0.950	32,200	

* See fifth footnote for exception.
† Average weights of other female northern pike from Houghton Lake.
‡ Eggs stripped from fish.
§ Collected by Dr. P. I. Tack from Houghton Lake.
‖ Collected by Dr. L. N. Allison from Fletcher Pond, Thunder Bay River.

total lengths were measured in millimeters, and the ovaries were removed and preserved in 10 per cent formalin.

Actual total counts of the eggs were made on all thirty specimens. In nineteen of the counts Carl B. Obrecht used a counting board, patterned after boards used in the East. He constructed it from a piece of black hard-rubber radio panel, $\frac{3}{8}$ inch thick and measuring 3 by 5 inches. He drilled in it 250 holes $\frac{1}{8}$ inch in diameter and $\frac{1}{8}$ inch deep. Each hole was lightly countersunk. Another board with slightly smaller holes was employed in counting the smaller eggs of winter-caught fish. In operating this board the well-separated eggs are merely spread over the surface so that they will lodge in the holes. After surplus eggs are removed, inspection reveals any empty holes, and the count of 250, minus the number of empty holes, is obtained.

To trace the growth of the eggs and the relationship between the various sizes present in an ovary diameter measurements of ova were made by means of an ocular micrometer in a compound binocular microscope. The magnifications used gave a value of 0.04 mm. for each micrometer unit for the small eggs, and 0.2 mm. for the large eggs. The diameter was determined by placing the micrometer in a horizontal position with respect to the field of the microscope and reading the vertical diameter of each egg, without regard to its shape or position in the field of the microscope. Owing to distortion in the process of preservation ova are seldom perfectly spherical, and this method obviated any selection of the longest or shortest diameter. It gave measurements of the longest diameter of some eggs, the shortest of others, and intermediate ones for still others. Clark (1925), who made a careful test of this method, found it to be reliable and the most satisfactory for constant use.

In order to show the growth history of the ova before the spawning season a random sample of eggs was obtained after all eggs in the ovary had been teased apart. Measurements of the diameter of the large ova were made at the lower magnification until 500 eggs from each fish had been recorded, and the process was then repeated at the higher magnification to obtain the measurements of 500 small ova. To present the relationship between the actual number of all eggs of each size in the ovary a section approximately $\frac{3}{8}$ inch wide and about an inch long was carefully teased from the center of the ovary of one fish, and measurements of all ova (totaling 3,688) were taken in the sample.

To correlate the egg production with the condition of the fish the coefficient of condition (K) was calculated by using the formula $K = \frac{W \times 100}{L^3}$, in which W is the weight in grams and L the standard length in centimeters.

Because of the difficulty and uncertainty ever present in determining the age of northern pike from examination of the scales age determinations are not included in this paper.

Number of Eggs per Female

The actual number of eggs contained in the thirty females (Table I) ranged from 7,691 (for a fish having a total length of 15.7 inches and weighing 11 ounces) to 97,273 (for a 35-inch pike weighing 170.5 ounces). The following are average figures: number of eggs

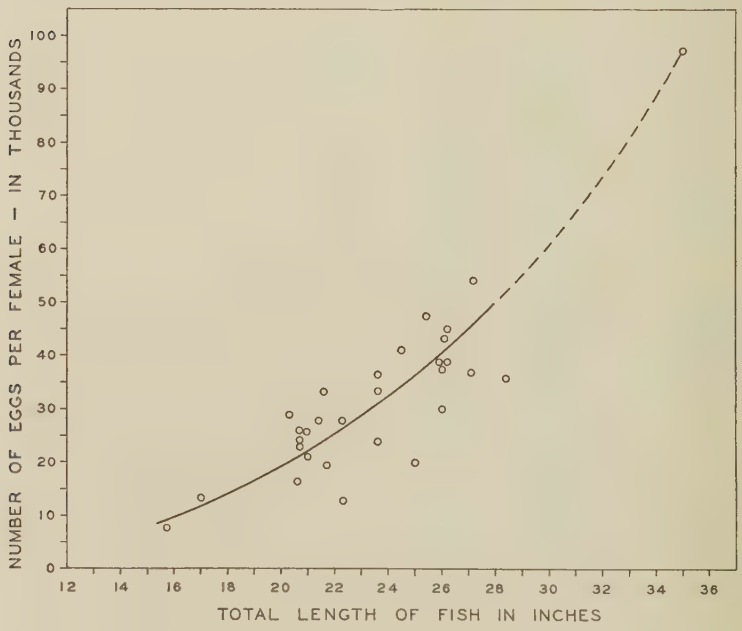

Fig. 1. Relation between the number of eggs and the total length of fish for thirty northern pike

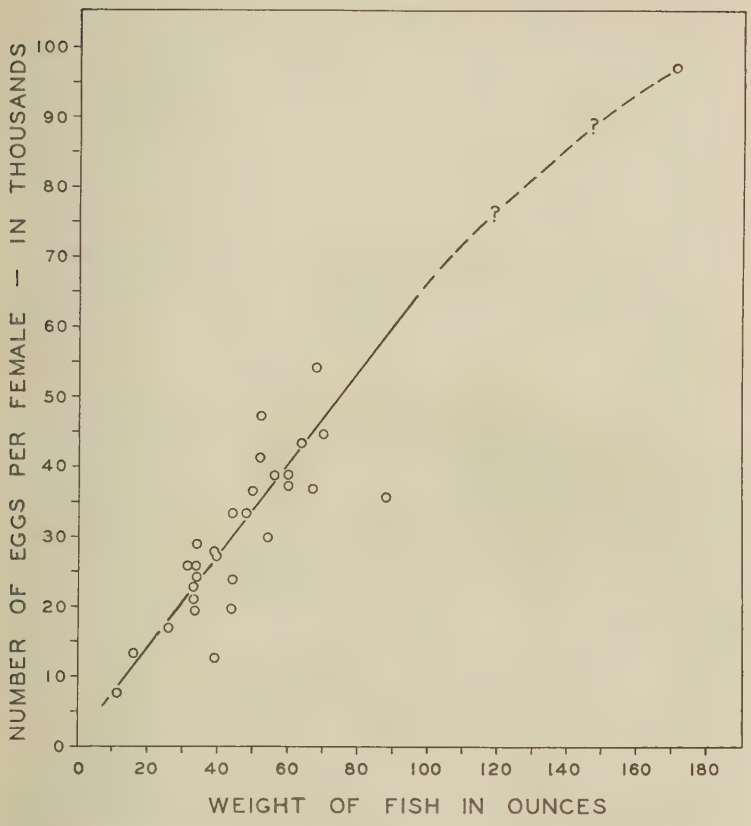

Fig. 2. Relation between the number of eggs and the weight of fish for thirty northern pike

produced, 32,200; total length, 23.6 inches; weight, 49.8 ounces. The average total length of the fish in the sample agrees closely with that of all females which entered the spawning grounds (23.5 inches in 1939; 23.2 inches in 1940; and 22.4 inches in 1942).

The number of eggs increases rapidly with increase in length of fish and is roughly proportionate to the weight (Figs. 1–2). In fish of any particular length or weight, however, it varies greatly.

Despite a large fluctuation there is some positive correlation be-

tween the condition of the female and its fecundity (Table I). The values for K fluctuate widely, and do not increase with size of fish; K averages 0.984 for the fourteen fish 15.7 to 22.3 inches long, and 0.919 for the sixteen that measure 23.6 to 35.0 inches. The specimen with the largest K value did, however, produce more eggs than other fish in the same general size range. Likewise, the fish having the lowest K value produced fewer eggs than other specimens in the same general size group. The six fish having the highest number of eggs, if the length of the fish is considered, and the six having the lowest number (as determined by the plus or minus deviation from the average line in Fig. 1) had average K values of 1.007 and 0.893, respectively.

Growth History of the Developing Ova

Because northern pike spawn but once a year and because the spawning season is of short duration the eggs of a female at spawning time are of two markedly distinct sizes: (1) large mature eggs and (2) almost microscopic immature ones. To demonstrate the history of the maturing ova and to check the assumption that all ova that are to be spawned in one year become distinguishable during the seasonal development from the small immature eggs, diameter measurements of ova were made from seven fish collected at various dates before the spawning season (Fig. 3A). The first specimen, a large fish from Drayton Plains hatchery stock known to be in its second year, was preserved on November 4. The fish of January 28 and February 4 and 25 were taken through the ice at Houghton Lake by fishermen. Those of March 27 and April 15 and 26 came from Peterson's Ditches during the spawning run. The one collected on March 27, a green female, and the one taken on April 15, a ripe female, were killed during the upstream migration to the spawning grounds.

The specimen secured on April 26 was one of several that entered the spawning marshes on April 10, at which time they were marked. This particular fish was seen to be ripe on April 10, for some eggs were lost during the process of weighing, measuring, and tagging. After spawning it returned from the marshes to the lake on April 25 with a serious head injury. On April 26 it was found dead, washed up on shore. The ovaries were then removed. This northern pike had therefore spawned some time during the seventeen-day period be-

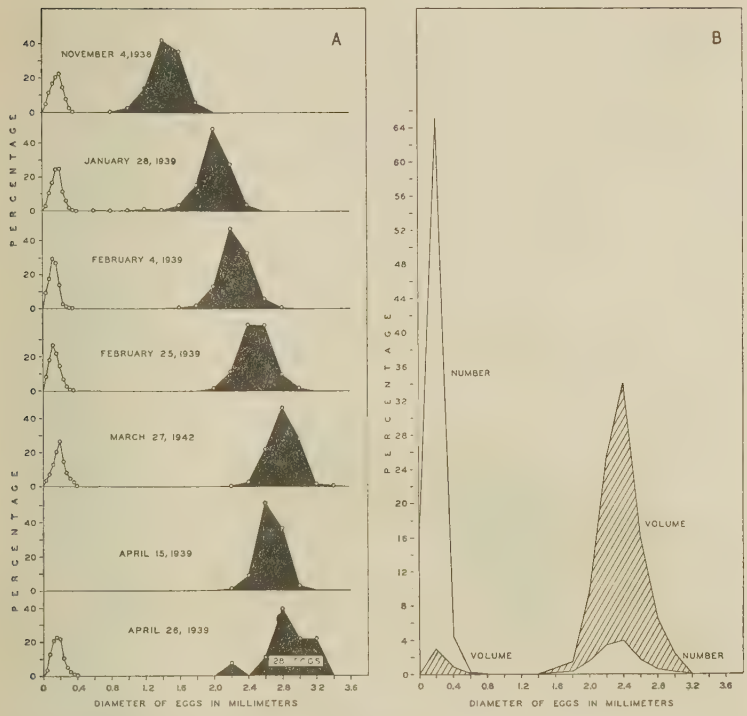

FIGURE 3

A. Frequency polygons showing the growth history of northern pike eggs collected before, during, and after the spawning season. Because each polygon was based on measurements of 500 eggs and because more and different size classes were used in measuring the immature ova, the areas of the polygons are not proportional to the numbers of immature and mature eggs present in the ovary. The fish collected on March 27 (a green female) and on April 15 (a ripe female, which was stripped) were killed on the upstream spawning run. See text (p. 128) for the data concerning the collection of the fish taken on April 26.

B. Frequency polygons showing the proportionate number and proportionate volume of the eggs of each size class in the ovary of a mature northern pike. Based on measurements of the 3,688 ova comprising a random sample of the ovary of a fish collected January 28, 1943, from the Fletcher Pond of the Thunder Bay River. The immature eggs were measured in size classes of 0.04 mm., but these were combined by fives to give size classes of 0.2 mm., to correspond with the measurements of the maturing eggs.

tween April 10 and 26. Because the fish was ripe when it entered the spawning grounds it is probably safe to assume that spawning occurred at least two weeks before the ovaries were removed and preserved. The ovarian wall had shrunk little during this period. Close examination revealed the presence of twenty-eight old, mature eggs held over from spawning. The few large eggs that were well preserved were free from the follicles; those that were still enclosed in the follicles showed varying degrees of resorption. In addition to the twenty-eight mature eggs a tremendous number of extremely small eggs were also present in the ovaries (Fig. 3A, bottom graph). Some of these eggs were granular in appearance and were apparently degenerating, because they were easily broken after preservation. The remainder of the small eggs still retained the nucleus and were the only ones measured.

In studying the growth of the ova (Fig. 3A) chief attention should be paid to the eggs with a diameter exceeding 0.4 mm., because these are the maturing eggs. Ova less than 0.4 mm. in diameter obviously remain immature through the late fall and winter; they constitute a distinct group of relatively uniform size in each adult female, during the fall and winter (Fig. 3A) and no doubt throughout the year. Any increase in size beyond 0.4 mm. indicates the beginning of the growth of the ova toward maturity for the next spawning season. We were unable to obtain a fish with ovaries at this stage. The specimen in the earliest stage in the growth of the ova was taken on November 4, approximately five months before spawning. Differentiation between the two sizes of eggs was already well marked.

The only fish with eggs of intermediate size was collected on January 28. The few eggs of this size had either started to develop a short time before this fish was killed or else had been retarded in growth.

On each succeeding date from November 4, 1938, to April 15, 1939, the maturing ova were found to have attained a constantly greater average diameter. The March specimen had mature eggs of the largest size, either because of individual variation or because the sample was taken in another year (1942).

Mature eggs of the northern pike range in diameter from 2.2 to 3.4 mm.

The immature eggs greatly outnumber the maturing eggs in an ovary of a pike about to spawn, but the volume of the maturing eggs

vastly exceeds that of the immature ones (Fig. 3B). To illustrate these relations, measurements were made of the diameter of all the 3,688 eggs comprising a random sample from the ovary of a fish collected on January 28, 1943 (this fish measured 27.1 inches in total length and weighed 67 ounces). The volume of the eggs in each size class was computed mathematically from the average diameter of each class. The number and the volume of the eggs in each size class were computed and expressed as the percentage of the total number and of the total volume, respectively.

Of the 3,688 ova that were measured the maturing eggs constituted 11.7 per cent by number and 95.9 per cent by volume, whereas the immature eggs made up 88.3 per cent by number and 4.1 per cent by volume. Since the total number of maturing eggs in both ovaries of this fish was 36,812 (by count), it is computed that these ovaries contained 278,089 immature ova. Enough small eggs for several spawnings were therefore present in the ovaries of this fish. I do not believe, however, that the 314,901 eggs estimated to be present in this fish would suffice for all spawnings of a pike that would reach a relatively large size and advanced age. A 35-inch pike was found to contain 97,273 mature eggs; in three years such a fish would produce more eggs than the total number of immature eggs estimated to occur in the 27-inch fish. Large pike show no apparent reduction in the relative number of immature ova. It is concluded that new eggs develop during the adult life of the pike. Some evidence was obtained to indicate that a number of the immature ova as well as all unspawned mature eggs are resorbed after the spawning time. Such loss would provide a further need for new egg production in the adults.

The ovary of the fish used in determining the number of eggs in each size group (see Fig. 3B) contained in its anterior, middle, and posterior parts mature ova of the following diameters, as determined by measurements of 500 eggs from each part:

Anterior part, 1.6 to 3.0 mm.; average $2.305 \pm .0103$ mm.;
Middle part, 1.6 to 3.0 mm.; average $2.355 \pm .0130$ mm.;
Posterior part, 1.6 to 3.0 mm.; average $2.304 \pm .0103$ mm.

The average size of the eggs is significantly larger in the middle part of this ovary than in the anterior and the posterior parts (the difference is about three times the standard error of the difference). The difference, however, is only about 0.05 mm. It is therefore concluded

that no considerable error was introduced by measuring the eggs (as for Fig. 3) from samples taken from the middle part only of each ovary.

The developmental cycle of the eggs in the northern pike is like that of the salmonoid fishes, lampreys, and other fishes that spawn over a very brief period. Many fishes, for instance, the halibut (Thompson, 1915), the grunion (Clark, 1925), and other species (Hickling and Rutenberg, 1936), deposit eggs more than once in a spawning season, and throughout most of this period have eggs of more than two size groups in the ovary. In addition to the reserve stock of minute ova and the group of maturing ova, one can usually distinguish groups of ova of one or more intermediate sizes. These ova are obviously being prepared for future periods of egg laying.

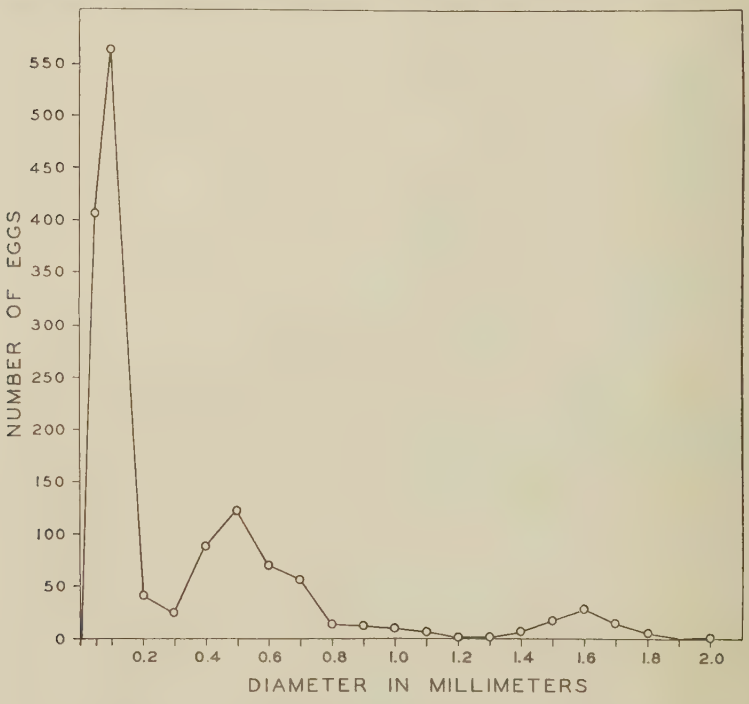

Fig. 4. Frequency polygon showing relationship of the number of eggs of various sizes present in a mud pickerel (*Esox vermiculatus*) taken April 2, 1941, from Whitmore Lake

In general, this type of egg development appears to be characteristic of families or at least of genera. It comes as a surprise, then, to learn that both types of egg development occur in the pike genus *Esox*. The mud pickerel, *Esox vermiculatus*, contains in its ovaries a group of eggs intermediate in size between the immature and the mature eggs. In the one mature female studied the immature eggs averaged about 0.1 mm. in diameter, and the seemingly mature (yellowish and rather free) eggs ranged in diameter from 1.2 to 2.0 mm. (Fig. 4). The mature eggs thus seem to average smaller than those of *Esox lucius*. The female of *Esox vermiculatus* that was studied measured 6.2 inches in total length, and was collected at Whitmore Lake, Washtenaw County, Michigan, on April 2, 1941, during the spawning period of this species, which coincides with or at least overlaps that of the northern pike. Newly hatched mud pickerel may be taken in early April in southern Michigan. The eggs of the intermediate size group ranged in diameter from 0.3 to 1.2 mm. It is estimated that the 6.2-inch mud pickerel contained a total of 15,732 eggs, of which 10,925 were immature, 4,004 of intermediate size, and 803 mature. Several spawnings during the spring are thus indicated. Occasionally mud pickerel spawn in the fall also, according to Lagler and Hubbs (1943).

PERCENTAGE SURVIVAL OF EGGS AND YOUNG ON THE SPAWNING GROUNDS

In the management of any species of fish knowledge of the natural mortality and of the probable yield from any spawning is obviously important. It is desirable to know at what stage of development the mortality rate is highest. In the experiments described in this paper a complete count was obtained of all adult northern pike migrating from Houghton Lake to the spawning grounds under observation, and in 1939 and 1940 complete counts were made of all young migrating from the marshes to the lake (Carbine, 1942). It is possible, therefore, to present figures indicating the survival of the young from the time of egg deposition until the last young pike had migrated from the marshes (a maximum period of 82 days from the time the first fry hatched in 1939 and of 85 days in 1940). Each year a portion of the young were fin-clipped before they were released in Houghton Lake in the hope that an estimate could be obtained of the percentage survival from the fingerling stage to that of legal size. Unfortunately

so few captures of these fish were reported (voluntary returns only were available) that this experiment was abandoned.

In 1942 all the migrating adults were trapped during the spawning run, but fry and fingerling weirs were not installed. On May 6, 1942, I stopped at Houghton Lake to check the success of the hatch of pike in the various marshes that had been under examination earlier in the year. It was surprising to find that Mr. John Peterson, who operates a resort near the marshes on which this investigation was being conducted, had installed and maintained weirs for trapping fry and fingerling pike, following the procedure previously used here (Carbine, 1942). During the past few years Mr. Peterson had become interested in our projects and desired to have as many pike as possible placed in Houghton Lake. He also wanted to compare the production obtained in 1942 with that of 1939 and 1940. He had been keeping accurate records of the number of young pike that were taken in the traps from the time of the first migration until about June 1 (when the weirs were removed). According to the records kept by Mr. Peterson up to May 6, slightly over 4,000 young northern pike had been taken in the traps and had been transferred to Houghton Lake. He estimated, from a two-hour tally, that approximately half of the fish went through some small holes in the wings of the weir rather than into the traps. Since his record book was unfortunately lost, it is not possible to give the exact estimate on the total run of young pike for 1942. The figure of 8,000 given for 1942, in Table II, a rough calculation, is considered to be a minimal estimate.

The eggs and young of the northern pike suffered an enormous mortality on the Houghton Lake spawning grounds that were under observation in 1939, 1940, and 1942 (Table II). The approximately four million eggs estimated to have been spawned in 1939 yielded only 7,239 migrating young — about 1,800 young for each million eggs. The mortality was computed to be 99.82 per cent. In 1940 about 700 young resulted from the deposition of a million eggs (mortality — 99.93 per cent) and in 1942, 4,400 young were produced per million eggs (mortality — 99.56 per cent).

The stage at which the greatest loss occurred was not determined. Observations in the marshes and ditches proved that very large numbers survived through hatching and the period of yolk absorption. As many as twenty very young pike were caught in a single dip of a small scap net. Gradually the numbers of young dwindled. Preda-

tion, including cannibalism, was observed, but the loss from each of many causes was not estimated.

The survival of eggs and young, 0.44 per cent, was relatively much higher in 1942 than in 1939 or 1940. The cause is thought to lie not in the smaller number of eggs laid, but rather in the higher water level. The marshes that provide the spawning and nursery waters for northern pike were more extensively covered in 1942 than in the other years, and remained covered for a longer period than in any of the last eight to ten years, according to local reports. The water level in 1942 did not become appreciably lower until all the fingerling pike had had a chance to move out to the lake.

TABLE II

Estimates of the Egg Production in Northern Pike and of the Survival of Eggs and Young up to the Time of Downstream Migration

Data obtained at Peterson's Ditches, Houghton Lake, Michigan

	1939	1940	1942
Number of spawning females	125	65	56
Number of spawning males	280	81	70
Ratio of males to females	224 : 100	125 : 100	125 : 100
Estimated number of eggs deposited*	4,025,000	2,093,000	1,803,000
Number of migrating young †	7,239	1,495	8,000
Percentage survival of eggs and young to time of migration	0.18	0.07	0.44

* Based on average of 32,200 eggs per female; see p. 127.
† See text in regard to estimate for 1942.

A very high mortality during the fry stage was also observed in the pike-propagation experiment conducted in 1937 at the Ortonville Rearing Pond of the Drayton Plains Fish Hatchery of the Michigan Department of Conservation. This three-acre pond was stocked with approximately 150,000 northern pike fry on May 3, 1937, and when it was drained on October 14 (171 days from the date of hatching) the total number of pike recovered was only 362. The mortality from the fry stage was 99.76 per cent, virtually identical with the average mortality of 99.77 per cent estimated to have occurred during the egg and early fingerling stages on the spawning grounds of Houghton Lake.

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I should like to express my appreciation to Albert S. Hazzard, director of the Institute for Fisheries Research, for assistance in planning the work and for suggestions and help in the preparation of this report. Thanks are also due to Carl B. Obrecht, who counted most of the eggs; to George N. Washburn and John T. Greenbank, who assisted in some of the egg counts; to Louis A. Krumholz, who drafted the figures; to David S. Shetter, Walter R. Crowe, and other members of the Institute, as well as to various officers of the Department of Conservation who assisted in the collection of material for the egg counts and in other phases of this investigation. I am indebted to Carl L. Hubbs for guidance and help in the analysis of the data and in preparation of the report.

SUMMARY

1. Investigation of the life history of the northern pike, with special emphasis on egg production and survival of eggs and young on the spawning grounds, was begun in 1939 and continued through the spawning season of 1942 at Houghton Lake, Michigan.

2. Most of the migrating young and adult northern pike were captured in weirs, although a few of the adults were caught by ice fishermen.

3. On the basis of actual counts of the eggs contained in the thirty northern pike the average number produced was estimated to be 32,200 (range 7,691 to 97,273).

4. The number of eggs increases rapidly with increase in length of the fish and is roughly proportionate to the weight.

5. Despite a great fluctuation there is some positive correlation between the condition of the female and the number of eggs produced.

6. Diameter measurements of ova made on seven fish collected before, during, and after the spawning season show that all eggs that are to be spawned in one season form a single size group, easily distinguishable throughout the seasonal development from the small immature eggs.

7. Mature eggs of the northern pike range in size from 2.2 to 3.4 mm.

8. The immature eggs present in the ovaries of a pike before the

spawning season constitute 88.3 per cent of the number and 4.1 per cent of the total volume, whereas the maturing eggs made up 11.7 per cent by number and 95.9 per cent by volume.

9. The presence in the ovaries of the mud pickerel *Esox vermiculatus* of eggs of intermediate size indicates that this species spawns more than once during one season and that one type of egg development is not characteristic of a genus.

10. A total of 125 females spawned in the marshes in 1939, 65 in 1940, and 56 in 1942.

11. The estimated egg production, based upon the average of 32,200 eggs per female, was 4,025,000 in 1939, 2,093,000 in 1940, and 1,803,000 in 1942.

12. The approximately four million eggs assumed to have been spawned in 1939 yielded only 7,239 young; in 1940 only 1,495 young hatched from about two million eggs; and in 1942 an estimated 8,000 young from 1,800,000 eggs. The mortality of eggs and young to the time when the young left the marshes is therefore estimated to have been 99.82 per cent in 1939, 99.93 per cent in 1940, and 99.56 per cent in 1942. The increased yield in 1942 seems to be correlated with a higher and more constant water level over the marshes.

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THE SALTICIDAE (JUMPING SPIDERS) OF MICHIGAN

ARTHUR M. CHICKERING

THE Salticidae or jumping spiders are mong the most interesting of our native araneids. They construct no true webs, but they build silken retreats, often cunningly devised, for the protection of the young and the concealment of the parent. They commonly make one or more frail cocoons, which they surround by a nest with one or two openings. Here in the north most of our species appear to lay their eggs early in the summer or late in the spring. The spiderlings are often guarded by the mother for a short time until they disperse to care for themselves. Upon the approach of winter the young probably spin, in some protected spot, a shelter within which they hibernate until the following spring.

The salticid spiders are active hunters, gifted with a keen vision, accurate judgment of distance, and skill in jumping. They spin a dragline wherever they go, and by means of it they can usually regain a position after springing away to capture an insect or to escape an enemy.

Although our northern salticid fauna is drab and somber when compared with the extraordinary richness, brilliance, and beauty of the family in the tropics, the jumping spiders of Michigan are worthy of a closer acquaintance than most people, even professional zoologists, have with them. This paper is presented with the hope that it will be a help to all who wish to become more familiar with the family. As was true of former papers in this series (1939, 1940), an attempt has been made to prepare the descriptions, keys, and drawings so that those with little zoological knowledge may use them to identify local salticids without a great deal of trouble. It must be admitted, however, that it is not easy to provide adequate keys for the separation of the salticid genera and even for certain of the species.

Several figures accompanying this paper were drawn from specimens in the collection of the Museum of Comparative Zoölogy at Harvard College and loaned to me by Miss Elizabeth B. Bryant,

of the museum staff. Dr. Willis J. Gertsch, American Museum of Natural History, New York City, kindly presented me with a male and a female *Phidippus altanus* Gertsch for comparison with my Michigan specimen. From the female I have made the first published drawing of the epigynum. All other drawings are from specimens in my private collection. The colors noted in the descriptions are always given as they appear in alcohol unless otherwise stated. In agreement with my usual practice I have included only the most essential synonymy.

Acknowledgments are gratefully extended as follows: to Mr. Nathan Banks and Miss Elizabeth B. Bryant, both members of the staff of the Museum of Comparative Zoölogy at Harvard College, for their continued interest in my work and their never-failing willingness to give me the privileges of the museum and its extensive library; and to that indefatigable collector, Mr. R. R. Dreisbach, Midland, Michigan, for the opportunity to examine his collection of spiders from the region around Midland County.

The thirty-nine species of Salticidae now known from Michigan may be listed as follows:

Admestina tibialis (C. L. Koch)
Evarcha hoyi (Peckham)
Fuentes lineata (C. L. Koch)
Habrocestum pulex (Hentz)
Habronattus agilis (Banks)
H. borealis (Banks)
H. decorus (Blackwall)
H. peregrinus (Peckham)
Hentzia mitrata (Hentz)
H. palmarum (Hentz)
Hyctia bina (Hentz)
Maevia vittata (Hentz)
Marpissa undata (De Geer)
Metaphidippus canadensis (Banks)
M. capitatus (Hentz)
M. flavipedes (Peckham)
M. montanus (Emerton)
Neon nellii Peckham
Paraphidippus marginatus (Walck.)
Peckhamia picata (Hentz)
Peckhamia scorpionia (Hentz)
Phidippus altanus Gertsch
P. audax (Hentz)
P. brunneus Emerton
P. clarus Keyserling
P. insigniarius C. L. Koch
P. pius Scheffer
P. purpuratus Keyserling
P. whitmanni Peckham
Phlegra fasciata (Hahn)
Salticus scenicus (Clerck)
Sitticus palustris (Peckham)
Synemosyna formica Hentz
Tutelina elegans (Hentz)
T. formicarius (Emerton)
T. hartii (Emerton)
T. similis (Banks)
Zygoballus bettini Peckham
Z. nervosus (Peckham)

Because the logical separation of the Salticidae into subfamilies is still very much in doubt I am making no attempt at classification within the family. Hence the simple alphabetical arrangement of all species in this paper.

BRIEF DIAGNOSIS OF THE FAMILY SALTICIDAE IN MICHIGAN

The cribellum, calamistrum, and colulus are all lacking. Six spinnerets with the anterior pair approximated, stouter than the others. Eight eyes, all diurnal, arranged in three rows; anterior medians very large; posterior medians, making up the second row, very small. Margins of the fang groove usually pluridentate, fissidentate, or unidentate. Legs prograde, adapted for jumping; without scopulae but with well-developed claw tufts; two claws, more or less dissimilar, pectinate in a single row. Tracheal spiracle close to base of spinnerets, with respiratory system extending into cephalothorax. (Modified from Petrunkevitch, 1939.)

KEY FOR THE SEPARATION OF THE GENERA OF MICHIGAN SALTICIDAE

1. Pedicel and at least posterior border of carapace overlapped by anterior end of abdomen; not distinctly antlike in form 2
1. Pedicel and posterior border of carapace not overlapped by anterior end of abdomen; distinctly antlike in form 19

2. Usually long and flattened; carapace at most only slightly more than one half as tall as wide at widest place 15
2. Usually not much elongated and not flattened; carapace considerably more than one half as tall as wide at widest place 3

3. Males with well-rounded palpal bulbs, having long curved emboli describing wide arcs from points of origin and long curved apophyses accompanying emboli (Figs. 17–21); females with epigyna having a more or less conspicuous tubular or conical central part and anterior curved margins (Fig. 24) ..... *Habronattus*, p. 151
3. Males and females without combination of characters given above for *Habronattus* 4

4. Very small spiders, when mature only 2 to 3 mm. long; eyes occupy more than one half of length of carapace, posterior eyes almost exactly as far apart as ALE; abdomen yellowish, with many dark narrow bars, oblique lines, and mottles ..... *Neon*, p. 178
4. Larger spiders, at least more than 3 mm. when mature; eyes always occupy less than one half of length of carapace except in *Zygoballus;* abdomen never barred, lined, and mottled as in Neon 5

5. Eyes occupy more than one half of length of carapace; carapace slopes steeply to posterior border from posterior eyes; first pair of legs much the stoutest; male chelicerae much enlarged ..... *Zygoballus*, p. 218
5. Not with combination of characters given for *Zygoballus* 6

6. Retromargin of fang groove with a fissidentate (compound) tooth; four pairs of anterior ventral tibial spines, third pair displaced laterally; two

pairs of anterior ventral metatarsal spines, more conspicuous in females than in males 7
6. Not with combination of characters given above 8

7. First pair of legs considerably enlarged; male palp large and complicated; epigynum with two oval depressions just in front of posterior margin; abdomen with longitudinal light and dark stripes ..... *Fuentes*, p. 147
7. First pair of legs not much enlarged; male palp not unusually large and not complicated; epigynum with a single small central depression far anterior; abdomen not conspicuously striped, but usually with a series of dorsal chevrons ..... *Maevia*, p. 165

8. Retromargin of fang groove without teeth; two pairs of anterior ventral tibial spines; carapace with a narrow white marginal line and three narrow dorsal white stripes, more conspicuous in males .. *Sitticus*, p. 206
8. Not with combination of characters given above 9

9. First pair of tibiae without ventral spines; cephalothorax long and narrow, with eye space occupying three sevenths of length of carapace; abdomen with a basal white bar and two pairs of dorsolateral bars *Salticus*, p. 204
9. Not with combination of characters given above 10

10. Males with palpal tibial apophysis a stout blunt extension longer than body of tibia and extending beyond middle of bulb; carapace with a dorsolateral white stripe on each side; abdomen nearly encircled by a dorsolateral light margin. Females with epigyna broader than long, with two large oblique depressions near posterolateral border; color variable but tending to be like that of males ..... *Evarcha*, p. 145
10. Males and females without combinations of characters given above 11

11. Male palpal tibia with a short, blunt, somewhat membranous ventral process; embolus curled nearly into a circle; female with epigynum having two large, nearly circular contiguous areas .. *Habrocestum*, p. 148
11. Males and females without combination of characters given above 12

12. Large robust spiders, up to 10 mm. or more; frequently hairy; cephalothorax only a little longer than wide, tall and convex laterally; thorax falls gently from posterior eyes and then more steeply to posterior border; ocular quadrangle about one third wider than long... *Phidippus*, p. 186
12. Relatively smaller spiders; less robust and without combination of characters given above 13

13. Carapace and legs a bright reddish brown, especially in males; middle row of eyes only slightly nearer to first row than to third; AME more than twice the diameter of ALE; PME less than one third of diameter of PLE; male chelicerae more or less produced 14
13. Carapace and legs a more somber color; body scaly and more or less iridescent; AME about twice the diameter of ALE; carapace not markedly convex, sides nearly parallel, usually about two thirds as wide as long ..... *Tutelina*, p. 210

14. Male chelicerae produced and excavated along fang groove; a fairly robust genus; first legs not much enlarged; carapace quite convex laterally ..... *Paraphidippus*, p. 179
14. Male chelicerae only mildly developed and not strongly excavated along fang groove; not a robust genus; first legs often enlarged; carapace less convex laterally ..... *Metaphidippus*, p. 169

15. First femora and tibiae much swollen; first ventral tibial spines entirely lacking; one pair of ventral metatarsal spines; first metatarsi shorter than first tarsi ..... *Admestina*, p. 143
15. Without combination of characters given above 16

16. Four pairs of first ventral tibial spines; carapace widest opposite beginning of last third; male palp with greatly swollen bulb, a robust curved tibial retrolateral apophysis, and a deep excavation along retrolateral side of cymbium; epigynum small, with two small depressions just anterior to marginal notch ..... *Hyctia*, p. 162
16. Fewer than four pairs of first ventral tibial spines; not with combination of characters given above 17

17. Cephalothorax as long as or longer than abdomen; carapace with two and abdomen with three narrow light longitudinal dorsal stripes *Phlegra*, p. 202
17. Combination of characters not as given above 18

18. Large species, about 9–10 mm. long; a broad dorsal central serrated light abdominal stripe ..... *Marpissa*, p. 167
18. Smaller species, about 4–5 mm. long; no such dorsal serrated stripe as in *Marpissa* ..... *Hentzia*, p. 159

19. Fang groove with a retromarginal fissidentate tooth; ocular area occupies more than one half of length of carapace; neither carapace nor abdomen deeply constricted ..... *Peckhamia*, p. 182
19. Fang groove with several simple retromarginal teeth; ocular area occupies less than one half of length of carapace; both carapace and abdomen deeply constricted in middle ..... *Synemosyna*, p. 208

Genus ADMESTINA Peckham, 1888

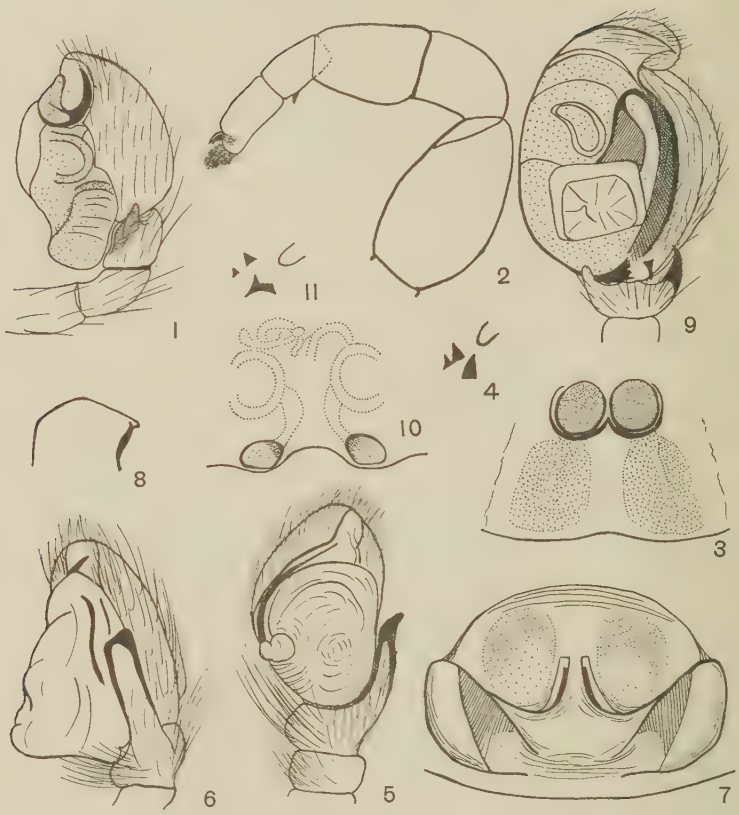
Small spiders. First leg with femur and tibia much enlarged. Fang groove with a single simple retromarginal tooth. First tibia without ventral spines; first metatarsus with one pair of stout ventral spines and shorter than first tarsus. Carapace low and flat, nearly twice as long as wide. Ocular region nearly twice as wide as long, occupies about one third of length of carapace. PME (small eyes of second row) nearer to ALE than to PLE. Only one species in Michigan.

Admestina tibialis (C. L. Koch)

(Figures 1–3)

Admestina wheeleri Banks, 1892.
Maevia tibialis Emerton, 1909.
A. tibialis Peckham and Peckham, 1909.

Male. — Length about 3.25 mm. Legs, 4132; first pair much thickened (Fig. 2). Anterior ventral tibial spines lacking; anterior



EXTERNAL ANATOMY OF SPIDERS

(Figures 1–11)

1. *Admestina tibialis*, male palpus, retrolateral view
2. *A. tibialis*, first leg of male
3. *A. tibialis*, epigynum
4. *Evarcha hoyi*, left male cheliceral teeth
5. *E. hoyi*, male palpus, ventral view
6. *E. hoyi*, male palpus, retrolateral view
7. *E. hoyi*, epigynum
8. *E. hoyi*, distal end of left maxilla
9. *Fuentes lineata*, male palpus, ventral view
10. *F. lineata*, epigynum
11. *F. lineata*, left male cheliceral teeth

metatarsi with one pair of ventral spines. Cephalothorax longer than wide in ratio of 59 : 37; only slightly swollen opposite second legs; low and flat with very little posterior declivity. Eyes occupy slightly more than one third of length of carapace; PME nearer to ALE than to PLE; width of clypeus nearly equal to one third of diameter of AME, which project considerably. Fang groove with a single small retromarginal tooth and two small promarginal teeth. Palp: femur strongly curved; tibia with a single stout retrolateral apophysis; bulb much swollen, with a short strongly curved embolus at the anterior end; patella slightly longer than short tibia (Fig. 1). Color: cephalothorax generally a dark mahogany brown, almost black in eye region, overlaid with white hairs; first pair of legs and palps brownish, other legs yellowish with dark annulations; abdomen with a broad lanceolate central dorsal brown stripe, with six pairs of more or less conspicuous lateral extensions; laterally the abdomen is yellowish, with many chalky white patches, and ventrally it is whitish, with a broad central dusky stripe and a pair of ventrolateral broken narrow dusky stripes.

Female. — First legs and palps essentially as in male, except that they are lighter, like the other legs. Epigynum with two shallow openings close together at some distance from the posterior margin, which is slightly notched, as shown in Figure 3.

Distribution. — Appears to be widely distributed over New England, southward to North Carolina, westward to Illinois and southwestward to Texas. Taken only once in Michigan, from pines and spruces; at Homer, Calhoun County, August, 1933.

Genus EVARCHA Simon, 1902

PME slightly nearer to ALE than to PLE; diameter of AME about 1.5 times that of ALE; AME separated from one another by about one ninth of their diameter, from ALE by about two ninths; diameter of PLE slightly more than three times that of PME. Anterior metatarsus just a little longer than anterior tarsus, but only about two thirds as long as anterior tibia; third legs a little longer than fourth legs. Carapace moderately high, very gently arched to three quarters of distance from PLE to posterior border and then steeply declivitous. Bulb of male palpus large, cone-shaped near base, blunt distally.

Evarcha hoyi (Peckham)

(Figures 4–8)

Hasarius hoyi Emerton, 1891.
Pellenes hoyi Peckham and Peckham, 1909.

Male. — Length about 5.2 mm. Legs, 1342; first pair only a little the stoutest. Three pairs of anterior ventral tibial spines (basal promarginal spine somewhat smaller and apparently overlooked by some authors); two pairs of anterior ventral metatarsal spines. Cephalothorax longer than wide in ratio of 19 : 14; gently rounded along lateral sides; rather high, with carapace a little more than two thirds as high as wide; gently rising from AME to PLE, then gently sloping to about one fifth from posterior border, then steeply declivitous to posterior border. Eyes occupy slightly less than one half of length of carapace; PME slightly closer to ALE than to PLE; anterior row a little longer than posterior row; PLE occupy about eleven thirteenths of width of carapace at that level. Maxilla with slightly hooked tooth on outer distal corner (Fig. 8). Fang groove with a single stout retromarginal tooth, two promarginal teeth (Fig. 4). Palp: body of tibia short, with a single long stout blunt somewhat flattened apophysis (Figs. 5–6) reaching beyond middle of bulb, which is much swollen into a conical structure invaginated a little at the apex; embolus a curved tube extending more than one fourth of distance around periphery of bulb. Abdomen: about as long as cephalothorax and pointed posteriorly. Color: extremely variable; cephalothorax usually with a dark patch surrounding ocular area, overlaid with considerable white hair; a dorsolateral light stripe begins at the clypeus on each side and extends nearly or quite to posterior border; beneath the stripes carapace is dark to ventral margin. Abdomen dark brown basally and laterally; a narrower yellowish region dorsolaterally almost encircles a darker dorsal area, which bears near posterior end a series of incomplete light and dark chevrons. First femora entirely brownish dorsally, remaining three pairs dark brown over distal halves only; other segments more or less mixed brown and yellowish.

Female. — Length about 6.2 mm. Legs, 3 = 412. Other characters essentially as in male except that color markings are more subdued. Epigynum with two rather large oblique depressions far apart near lateral margins (Fig. 7); no notch in posterior border.

Distribution. — Widely distributed over the eastern part of the United States; also known from southeastern Canada; reported from Brazil. One of our common salticids; taken in many localities in both Northern and Southern peninsulas of Michigan.

Genus FUENTES Peckham, 1894

Carapace rather low, quite flat, with lateral sides only a little swollen, cephalic part very slightly inclined, thoracic part gently declined in first half, then steeply declivitous to posterior border. Ocular region occupies a little less than half the length of carapace, about one fourth wider than long, very slightly wider behind than in front, anterior row of eyes recurved, all close together. Diameter of AME greater than diameter of ALE in ratio of 7 : 4; PME a little nearer to PLE than to ALE; third row occupies about nine tenths of width of carapace at that level. Chelicerae not strongly developed, parallel, vertical with a single broad fissidentate retromarginal tooth on fang groove. First pair of tibiae with four pairs of ventral spines not all in regular order.

Fuentes lineata (C. L. Koch)

(Figures 9–11)

Maevia lineata C. L. Koch.
Icius lineatus Peckham, 1888.
Menemerus lineatus Emerton, 1891.
Onondaga lineata Peckham, 1909.

Male. — Length about 3.3 mm. Legs, 1423; first pair considerably enlarged, slightly fringed. Spines: first pair of tibiae with four pairs of ventral spines, the third pair distinctly offset laterally and all four along promargin displaced so far laterally as to make them appear to some as lateral instead of ventral in position; second pair of tibiae with one pair of ventral terminal spines and two more along retromargin; first two pairs of metatarsi each with two pairs of ventral spines. Outer distal corners of maxillae with a distinct hook. Eyes generic in position and relationships. Fang groove generic in respect to teeth (Fig. 11). Palp: tarsus very large, complicated; tibial retrolateral apophysis a short hooked spur; embolus starts near middle from expanded base, turns retrolaterally and continues to base, turns again and extends along whole prolateral side of tarsus to distal end nearly in a semicircle (Fig. 9). Color: first femora yel-

lowish above and below but reddish brown prolaterally and retrolaterally; first tibiae entirely reddish brown; first patellae darkened proximally but otherwise yellowish; first metatarsi darkened somewhat; first tarsi yellowish; all other legs yellowish-spotted and ringed with reddish brown. Eyes on black areas. Whole dorsal region of carapace except eyes amber color; two dark spots just behind AME showing through chitinous covering such as is often seen in other members of this division; a narrow broken black streak from longitudinal thoracic groove backward to near posterior margin and forward a short distance; a narrow black marginal line and two broad dorsolateral dark brown irregular stripes from posterior eyes to posterior margin. Abdomen yellowish, with four narrow broken dark brown dorsal lines; lateral sides spotted with brown.

Female. — Length about 4.2 mm. Legs, 4123. Spines like those in male except that second tibiae have no terminal ventrals. Color like that of male except that it is much darker; abdomen has a light brown central stripe with yellow margins; on each side of this central stripe is a broad darker brown stripe. Otherwise essentially like the male. Epigynum: a broad but shallow notch in posterior border; at each side of the shallow notch is an oval depression; anteriorly a series of coils of an internal tube (Fig. 10).

Distribution. — Known from Labrador, New England, a few scattered localities along the Atlantic coast to Florida, New York, Michigan, Wisconsin, and westward to Kansas. Collected in Michigan only once: Waterloo Recreational Area, Jackson County, May, 1941.

Genus HABROCESTUM Simon, 1876

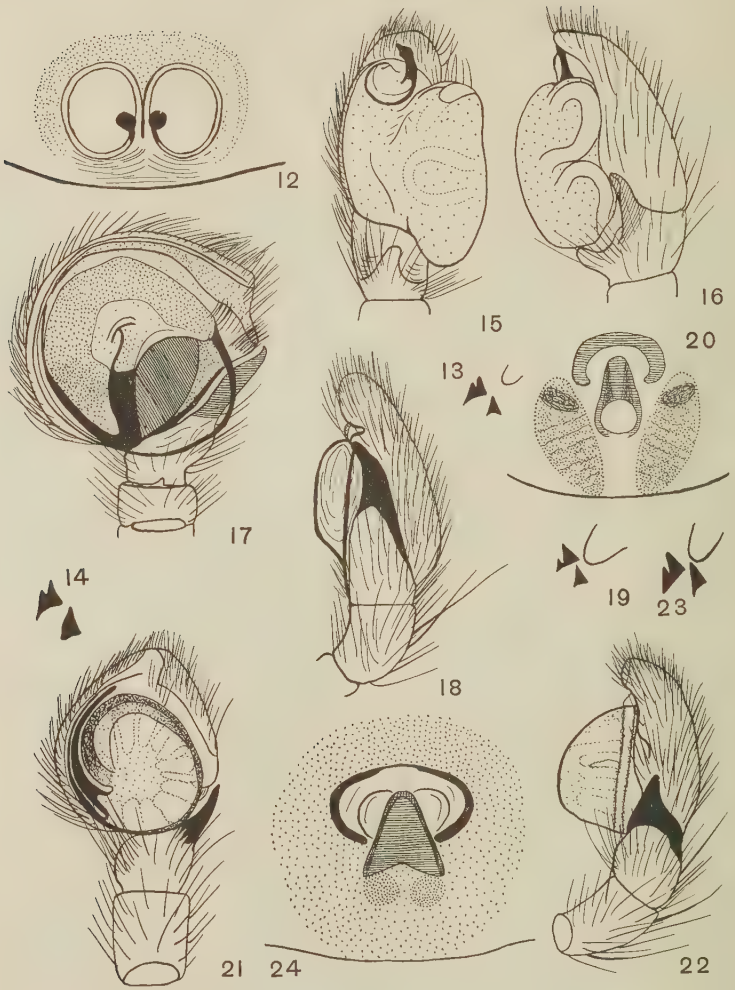
The original definition of the genus must be modified for American species. This description is intended only as a working basis for a more critical definition. Cephalothorax high and convex dorsally, highest just in front of PLE; lateral sides nearly parallel; cephalic part inclined forward, thoracic part descends gently from PLE and then very steeply through the last fifth. Ocular region a little wider than long, occupies about two fifths of length of carapace, a little wider in front than behind. AME less than twice as large as ALE; PME nearly equidistant between ALE and PLE. PLE about three times as large as PME.

Habrocestum pulex (Hentz)

(Figures 12–16)

Attus pulex Hentz, 1846.
Saitis pulex Emerton, 1891.
H. pulex Simon, 1901.

Male. — Length about 4.0 mm. Legs, 3 = 42 = 1; first and second pairs a little less than three fourths as long as third and fourth pairs. Anterior ventral tibial spines probably not as recorded by the Peckhams (1909); two along retromargin (none terminal) and only one along promargin (terminal); two pairs of anterior ventral metatarsal spines. Cephalothorax longer than wide in ratio of about 3 : 2; lateral sides nearly parallel, with only little widening opposite second coxae; of moderate height; rises considerably from AME to PLE, then descends very slightly to steep posterior declivity, which is about one fifth from posterior margin. Eyes occupy about three sevenths of length of carapace; PME a little closer to PLE than to ALE; anterior row a little longer than posterior row; PLE occupy about five sixths of width of carapace at that level. Maxillae with a small tooth on outer distal corner. Fang groove with a single fairly stout retromarginal tooth and a compound promarginal tooth (Fig. 14). Palp: body of tibia short with a short blunt somewhat membranous ventral process and a fairly stout well-chitinized retrolateral apophysis about as long as body (Figs. 15–16); bulb swollen retrolaterally and with a distal embolus curled almost into a circle ending in a stout spine. Abdomen: shorter by about one seventh than the cephalothorax, thirteen fifteenths as wide in the middle as long. Color: somewhat variable; a dark brown quadrilateral area, which is scalloped behind, encloses the eyes, and is somewhat overlaid with whitish hairs; remainder of carapace yellowish, with dark radial streaks. Abdomen with dark brown venter and lateral sides, both dotted with yellow; dorsally with a median central light stripe reaching back to a light transverse zigzag bar. The Peckhams' Figure 11, Plate XLII (1909), is a good drawing of the color pattern. Legs: coxae, femora, and patellae light dorsally but dark laterally and on the last two pairs of legs also ventrally; last three segments of first pair of legs all dark; on second pair all but tarsi, which are lighter; other segments mixed brown and yellowish. All segments of palps except tibiae and tarsi light yellowish.



EXTERNAL ANATOMY OF SPIDERS

(For explanation of figures see facing page.)

Female. — Length about 5.25 mm. Legs, 4312. Anterior tibiae have only two retromarginal ventral spines, with none terminal and one promarginal ventral, which is terminal. Color markings similar to those of male except as follows: dark ocular area less definite; a somewhat vague light triangular area behind eye region and lateral sides of cephalothorax are darker; light and dark abdominal areas less definite and more subdued. Epigynum with a pair of somewhat oval contiguous areas each bounded by a definite margin (Fig. 12); no distinct notch in posterior border.

Distribution. — Southeastern Canada; widely distributed over most of the United States east of the Mississippi River and westward into Kansas and Iowa, and probably into surrounding states. Known from both peninsulas of Michigan; appears to be common, especially in the southern part of the state.

Genus HABRONATTUS F. Cambridge, 1901

Also known under the names *Attus*, *Ephippus*, *Habrocestum*, *Hasarius*, *Evarcha*, and, most commonly, *Pellenes*. Carapace: rather high; considerably swollen laterally and widest opposite second coxae; noticeably wider below than above; only a little more than two thirds as wide as long. Ocular quadrangle about two thirds as long as wide. Eyes occupy about two fifths of length of carapace. Middle row usually midway between first and third rows. Males frequently have some modification of first and third legs which helps to distinguish them. Chelicerae normal in both sexes. Male palps always with expanded, rounded tarsus, with a long slender embolus

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EXPLANATION OF FIGURES 12–24

12. *Habrocestum pulex*, epigynum
13. *H. pulex*, left female cheliceral teeth
14. *H. pulex*, left male cheliceral teeth
15. *H. pulex*, male palpus, ventral view
16. *H. pulex*, male palpus, retrolateral view
17. *Habronattus agilis*, male palpus, ventral view
18. *H. agilis*, male palpus, retrolateral view
19. *H. agilis*, left male cheliceral teeth
20. *H. agilis*, epigynum
21. *Habronattus borealis*, male palpus, ventral view
22. *H. borealis*, male palpus, retrolateral view
23. *H. borealis*, left male cheliceral teeth
24. *H. borealis*, epigynum

curled around much of the bulbar periphery accompanied by a slender guard or apophysis (Fig. 17). Females are difficult to determine, but they all have epigyna constructed on a standard pattern: a simple curved posterior border with no notch; a somewhat truncated central conical tube more or less surrounded by a well-defined curved margin (Fig. 20).

KEY TO THE SPECIES OF *HABRONATTUS*

MALES

1. Distal end of third patella provided with a stout spur (Fig. 28); tarsal apophysis arising at base of bulb, not at all lateral (Fig. 25) *H. peregrinus*, p. 158
1. No spur at distal end of third patella; tarsal apophysis arising either from center of bulb or from a somewhat lateral position 2

2. Tarsal apophysis arising near center of bulb (Fig.17); embolus arising near tip of tibial apophysis and making a nearly complete circle around bulb *H. agilis*, p. 153
2. Tarsal apophysis arising from periphery of bulb; embolus arising far from tip of tibial apophysis and passing no more than halfway around bulb ... 3

3. Abdomen a bright iridescent red; first legs without decorative fringes; embolus passes around fully one half of circumference of bulb (Fig. 30) *H. decorus*, p. 155
3. No red on abdomen; first legs with a small and poorly developed fringe on prolateral surface of first femora; embolus passes only about one third of way around bulb (Fig. 21) ..... *H. borealis*, p. 154

FEMALES

1. Tubelike center of epigynum small and only slightly narrower at anterior end (Fig. 29) ..... *H. peregrinus*, p. 158
1. Tubelike center of epigynum larger than in *H. peregrinus* and very much narrower at anterior end 2

2. Tubelike center of epigynum with a circular opening; a complete broad anterior rim to epigynum; two large spermathecae obliquely placed and bounding this organ laterally (Fig. 20) ..... *H. agilis*, p. 153
2. Tubelike center not with a circular opening; epigynum not with a complete broad anterior rim; spermathecae either small or, if large, not oblique in position 3

3. Anterior rim of epigynum definitely divided into two somewhat crescentic ridges; spermathecae large and lateral to tubelike center (Fig. 33) *H. decorus*, p. 155
3. Anterior rim of epigynum not completely divided as in *H. decorus;* spermathecae small and immediately behind central tubelike center (Fig. 24) *H. borealis*, p. 154

Habronattus agilis (Banks)

(Figures 17–20)

Habrocestum agilis Banks, 1893.
H. auratum Emerton, 1902.
Pellenes agilis Peckham and Peckham, 1909.

Male. — Length a little more than 5 mm. Legs, 3412 (the Peckhams, 1909, 3142); first pair only moderately enlarged; with femora, patellae, and tibiae usually moderately fringed (sometimes heavily so, as drawn by the Peckhams, 1909). Anterior tibiae with three ventral retromarginal spines but only one ventral promarginal terminal; anterior metatarsi with two pairs of ventral spines. Cephalothorax quite robust as compared with rather small abdomen. Fang groove with a single retromarginal tooth and two promarginal teeth, the inner of which is much the smaller (Fig. 19). Palp: body of tibia short and broad; retrolaterally drawn out into a long stout somewhat sinuous apophysis (Fig. 18); numerous white clavate scalelike hairs on tarsus, tibia, and patella; prolateral fringe of clavate hairs and dorsal fringe of simple long curved hairs on femur; tarsus large-rounded, somewhat flattened; embolus arises close to apex of tibial apophysis and makes a complete circle ending just distal to its origin; tarsal apophysis arises near middle of bulb, extends proximally to basal end, then turns sharply to prolateral side and curves around the periphery of the bulb about one third of its circumference (Fig. 17). Abdomen: about seven eighths as long as the cephalothorax; about five sevenths as wide as long (including anal tubercle); ovoid. Color: carapace dark brown with well-developed covering of mixed black and light brown hair; between and below ALE and PLE are several long slender black bristles not forming definite tufts; a band of somewhat shorter, stiffer bristles lies above AME; beginning just posterior to ALE are two white stripes about as wide as these eyes and extending backward just above the PLE, converging a little toward the posterior border, which they do not quite reach; the clypeus is white, with a white band reaching back on each side along the margin in a broad stripe to posterolateral corner leaving posterior border dark brown; abdomen with a central dorsal whitish stripe, which does not reach to anal tubercle but anteriorly connects with a basal band that extends dorsolaterally back to base of spinnerets. White stripes composed of clavate hairs. At one place the marginal

cephalothoracic stripe is interrupted, and a tuft of long simple white hairs projects over the interval between the first and second coxae.

Female. — Length about 5.75 mm. Legs, 3412. Anterior ventral tibial spines same as in male except that distal retromarginal spine appears to be lacking. Color: in general like that of male with following exceptions: cephalothorax not so dark; a short median dorsal stripe reaching from between AME nearly to posterior row of eyes (mentioned by the Peckhams in males but it seems to be missing in this sex in my specimens). Clypeus is white in center with a dark patch on each side. White marginal cephalothoracic stripe turns upward anteriorly and disappears just lateral to AME. Abdomen also somewhat lighter; whitish stripes more broken. Epigynum: follows usual pattern, with a recurved crescentic anterior margin, tubular center and two large obliquely placed spermathecae (Fig. 20).

Distribution. — Appears to be widely distributed over the eastern part of the United States, westward to Kansas, southwestward to Texas and New Mexico. Collected from a few localities in the Southern Peninsula of Michigan.

Habronattus borealis (Banks)

(Figures 21–24)

Habrocestum borealis Banks, 1895.
Pellenes borealis Peckham and Peckham, 1909.

Male. — Length about 5.5 mm. Legs, 3412; first pair only moderately enlarged; no decorative fringes as in *H. agilis* except a small prolateral one poorly developed on each anterior femur. Anterior tibiae with three retromarginal ventral spines and one (terminal) promarginal spine. Fang groove with a single fairly stout retromarginal tooth and two promarginal teeth, of which the inner is somewhat the smaller (Fig. 23). Palp: tibia short but fairly stout, with a broad apophysis about as long as tibial body; numerous white clavate hairs all over the femur and dorsally on patella and tibia; with no special fringes; tarsus large, rounded; bulb much thickened; embolus arises near bulbar base on prolateral side and passes about two fifths of distance around the bulb accompanied by a fairly stout apophysis, which arises close to base of embolus and curves about one third of distance around bulb (Figs. 21–22). Color (only a single mature male from which to make observations): carapace generally very dark brown, with many whitish clavate hairs, which give a gray-

ish effect (since whitish hairs are easily brushed off in handling, different color patterns are easily produced); many black bristles in eye region not tufted together; first coxae, first trochanters, and mouth parts all dark brown; remaining coxae and trochanters progressively lighter toward posterior end; elsewhere legs yellowish; palpal segments except tarsus dark brown beneath white hairs; dorsally abdomen dark brown, with a white central spot about two thirds of distance from base to spinnerets, and a narrow recurved band which connects with a broad whitish margin encircling whole abdomen.

Female. — Length about 6.0 mm. Legs, 3412. Color: carapace fundamentally dark brown like that of male, but a dirty white hairy covering gives it a grayish appearance in unrubbed specimens; abdomen still more completely covered with yellowish white hairs, giving a glossy yellowish color; in rubbed specimens abdominal color pattern resembles that of male; legs and palps yellowish below, darker above. Epigynum: an ovate marginal rim almost encloses the central tubular structure, which is nearly as broad at posterior end as it is long (Fig. 24). Otherwise essentially similar to male.

Distribution. — A northern species known from New England, New York, Michigan, Wisconsin, and probably other northern states and Canada. My Michigan specimens have all come from three counties in the northern part of the Southern Peninsula.

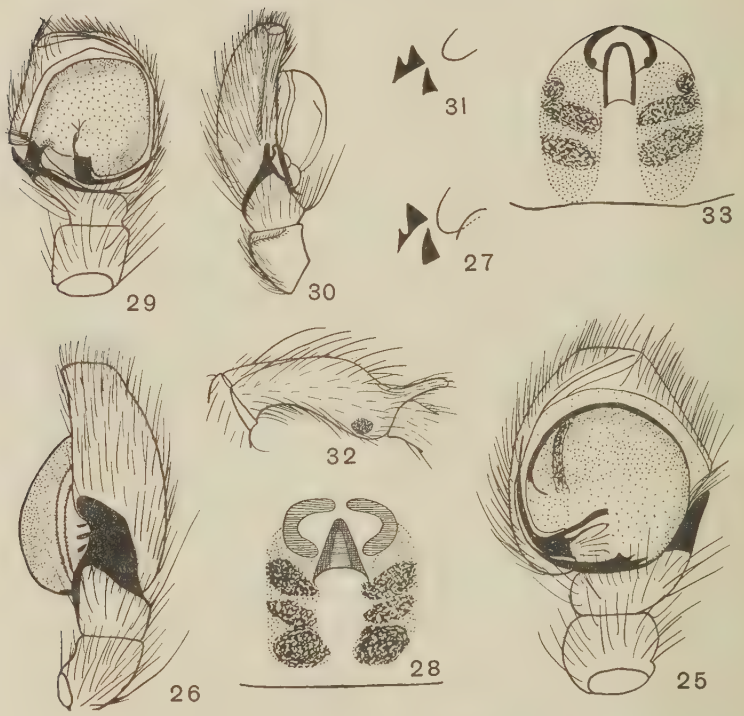
Habronattus decorus (Blackwall)

(Figures 25–28)

Salticus decorus Blackwall, 1846.
Attus roseus Hentz, 1846.
A. splendens Peckham, 1883.
Pellenes roseus Peckham and Peckham, 1909.
P. splendens Peckham and Peckham, 1909.

Note. — The synonymy is in some doubt, but I cannot improve it until more attention is given to the genus.

Male. — Length about 5.0 mm. Legs, 3412; first pair only a little stouter than others; without fringes. Spines: anterior tibiae with three pairs of ventral spines, but the first and second on the promargin so far prolateral that they could be regarded as prolateral instead of ventral in position; second tibiae with a pair of terminal ventral spines, but only two others along the retromargin, with those on the promargin entirely lacking. Cephalothorax slightly longer than abdomen and fairly stout. Eyes occupy about three eighths



EXTERNAL ANATOMY OF SPIDERS

(Figures 25–33)

25. *Habronattus decorus*, male palpus, ventral view
26. *H. decorus*, male palpus, retrolateral view
27. *H. decorus*, left male cheliceral teeth
28. *H. decorus*, epigynum
29. *Habronattus peregrinus*, male palpus, ventral view
30. *H. peregrinus*, male palpus, retrolateral view
31. *H. peregrinus*, left male cheliceral teeth
32. *H. peregrinus*, third patella of male
33. *H. peregrinus*, epigynum

of length of carapace. Fang groove with a single fairly robust retromarginal tooth and two promarginal teeth close together, with inner one small and slender (Fig. 27). Palp: body of tibia short and broad, drawn out retrolaterally into a stout apophysis, which reaches a little

more than two fifths of length of tarsus (Figs. 25–26); embolus originates at base of tarsus and without elbow extends a little more than halfway around circumference of bulb; tarsal apophysis has a sharp elbow, not quite a right angle, and extends a little more than one fourth of circumference of bulb, which is moderately swollen. Color: most brilliant of the Michigan habronattids; whole ocular area almost black, overlaid with a heavy coating of white scales, just behind this area is a light yellowish band somewhat curved posteriorly; elsewhere carapace is brownish, with many fine irregular lines all overlaid with many white scales; a fine black marginal line along ventral margin of carapace; whole clypeus covered by snowy-white hairs and scales. Anterior femora with a black prolateral stripe. A dark patch at base of abdomen dorsally; just behind this a light transverse band; nearly whole dorsum covered by a dark patch overlaid with azure iridescent scales, also with a good deal of reddish pigment; laterally reddish; venter yellowish with no stripes. Peckham's description states that the whole carapace and clypeus are covered with blue scales. Examination of specimens in the collection of the Museum of Comparative Zoölogy, Harvard College, indicates considerable variation in coloration among different individuals.

Female. — Length about 6.4 mm. Generally like the male except in secondary sexual characters and color. Color: differs from male essentially as follows: carapace with fewer white hairs; no prolateral stripes on anterior femora; azure-blue scales, iridescence, and bright red pigment seem to be entirely lacking on the female abdomen. Instead there is a dark-brown basal band, which continues on each side to become narrow ventrolateral stripes; some distance posteriorly there is another dorsal band, which continues laterally on each side as a stripe almost to the spinnerets; also a central light-colored broken sagittate mark and a broken dark-brown stripe on each side of it; background of abdomen is light yellow. Epigynum: follows usual pattern with anterior crescentic margin divided into two smaller lateral crescents facing each other; tubular central part pointed anteriorly and broad posteriorly (Fig. 28).

Distribution. — Reported from southeastern Canada, along the Atlantic seacoast to Florida and through the northern states from New England to Washington and Oregon. Collected only twice in Michigan: Calhoun County, May, 1935; Otsego County, July, 1938.

Habronattus peregrinus (Peckham)

(Figures 29–33)

Attus peregrinus Peckham, 1883.
Habrocestum peregrinum Emerton, 1891.
Pellenes peregrinus Peckham and Peckham, 1909.

Male. – Length about 5.0 mm. Legs, 3412; first pair somewhat fringed. First and second tibiae with a pair of ventral terminal spines and two more along retromargin, with none to match along promargin. First two pairs of metatarsi with two pairs of ventral spines each. Third patellae with a single stout distal spur (Fig. 32). Cephalothorax rather robust, about as long as abdomen, longer than wide in ratio of 41 : 30. Eyes occupy about two fifths of length of carapace. Fang groove with a single slender retromarginal tooth and a pair of promarginal teeth close together, with inner somewhat the smaller (Fig. 31). Palp: body of tibia short and broad; retrolaterally drawn out to a stout, terminally slender apophysis (Fig. 30), which reaches only about one fourth of length of tarsus; tarsus large, with swollen bulb; embolus rises near apex of tibial apophysis and curves about three quarters around bulb, with right angle near its base; tarsal apophysis arises near proximal end, makes a right-angle turn at base, and extends around less than one fourth of circumference of bulb (Fig. 29). Abdomen: about as long as cephalothorax; about three quarters as wide as long; broad at base, widest about two fifths from base and tapered to a point posteriorly. Color: carapace dark brown with a narrow white marginal band of scales (easily rubbed off), which continues as a narrow band across clypeus; ocular area darker, with many nearly white scales (in undisturbed condition); behind this darker area is a lighter one with two whitish bands diverging to posterolateral corners of carapace; sternum dusty yellow. Viewed dorsally, abdomen shows three nearly white longitudinal stripes enclosing two dark stripes; ventrally abdomen has three narrow broken black stripes separated and bounded by narrow yellowish stripes.

Female. – Length about 5.75 mm. Spines essentially like those in male. Color: like that of male, with all contrasts much subdued. Epigynum: the usual general pattern; recurved crescentic anterior margin relatively smaller and reduced in middle; tubular central piece only slightly broader posteriorly than anteriorly (Fig. 33).

Distribution. — Appears to be widely distributed over the eastern

half of the United States. Collected in Michigan only from the region around Marquette in the Northern Peninsula.

Genus HENTZIA Marx, 1883

Usually known as *Wala*; also formerly widely known as *Anoka*. Cephalothorax rather flat, of moderate height, only slightly longer than wide, widest just behind ALE. Ocular region one third wider than long, a little wider behind than in front, occupies two fifths of length of carapace. First legs in male much the longest. Abdomen long and slender. PME about halfway between ALE and PLE; third row somewhat narrower than carapace at that level. First coxae separated by more than width of labium, which is twice as long as wide. Two species occur in our Michigan fauna.

KEY TO THE SPECIES OF *HENTZIA*

MALES

1. First pair of legs reddish brown; chelicerae reddish brown and more or less porrect and flattened; abdomen with a broad central reddish stripe without spots ..... *H. palmarum*, p. 161
1. First pair of legs yellowish white; chelicerae yellowish white, vertical and not flattened; abdomen with several central dark spots *H. mitrata*, p. 159

FEMALES

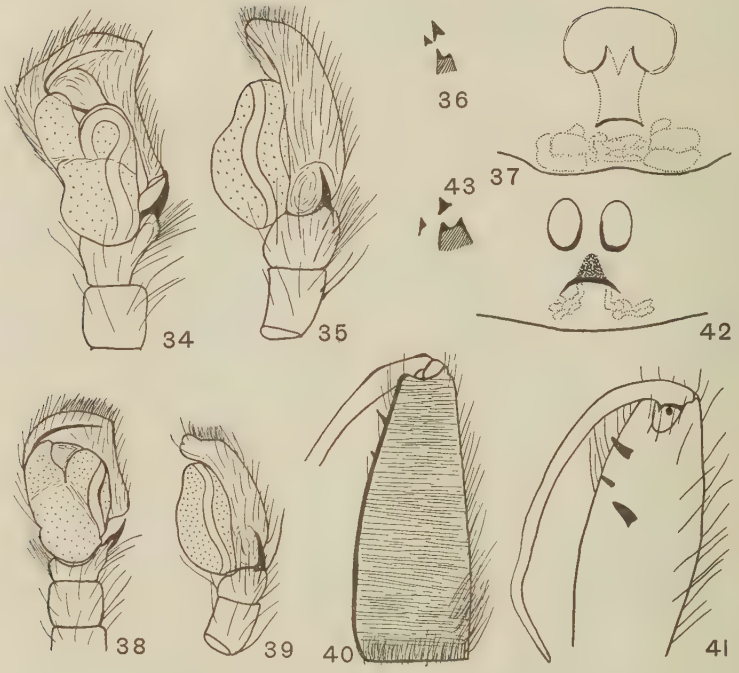
1. Abdomen yellowish white with a central reddish light-brown, more or less broken and sometimes obscure stripe composed of spots and dots; no dorsal spines on patellae ..... *H. palmarum*, p. 161
1. Abdomen yellowish white with three pairs of reddish-brown dorsal spots more or less coalesced; patellae with single dorsal spines *H. mitrata*, p. 159

Hentzia mitrata (Hentz)

(Figures 34–37)

Attus mitratus Hentz, 1845.
Anoka mitrata Peckham, 1894.
Wala mitrata Peckham and Peckham, 1909.

Male. — Length about 4.5 mm. Legs, 1423; first pair much the longest, fringed with many white hairs; other legs nearly equal to one another in length; anterior tibiae longer than anterior patellae. Anterior tibiae with three pairs of ventral spines; second tibiae with a pair of terminal ventral spines but with only one other spine, a retromarginal one near the base. First and second metatarsi with two pairs of ventral spines. Carapace longer than wide in ratio of



EXTERNAL ANATOMY OF SPIDERS

(Figures 34–43)

34. *Hentzia mitrata*, male palpus, ventral view
35. *H. mitrata*, male palpus, retrolateral view
36. *H. mitrata*, left male cheliceral teeth
37. *H. mitrata*, epigynum
38. *Hentzia palmarum*, male palpus, ventral view
39. *H. palmarum*, male palpus, retrolateral view
40. *H. palmarum*, male chelicera, dorsal view
41. *H. palmarum*, left male chelicera and teeth
42. *H. palmarum*, epigynum
43. *H. palmarum*, left female cheliceral teeth

about 30 : 23, somewhat flattened. Ocular region wider than long in ratio of about 35 : 26, middle eyes closer to ALE than to PLE in ratio of 7 : 10. Eyes occupy about two fifths of length of carapace. Chelicerae vertical and of moderate size; fang groove with two slender

promarginal teeth, inner one very small, and a single fissidentate retromarginal tooth (extent of fissidentation variable among different individuals [Fig. 36]). Much long white hair on palps and chelicerae. Palp: patella about equal in length to that of tibia; tarsus much broader anteriorly than at base; with a conspicuous twisted tube in bulb (Figs. 34–35). Abdomen: longer than wide in ratio of about 5 : 2, only slightly flattened, widest about two fifths from base. Color: all appendages and sternum except lip a yellowish white; carapace a reddish brown throughout ocular area and back to posterior margin; lateral sides and clypeus yellowish white; abdomen reddish brown dorsally, with three pairs of brown spots more or less coalesced, while laterally yellowish and reddish narrow stripes alternate, and ventrally there are four narrow light-colored broken stripes surrounded by light reddish areas.

Female. — Length about 5.0 mm. Spines essentially like those of male except that female has a single dorsal spine on each patella whereas the male has none. Other features including color essentially like those of the male. Epigynum: a small opening indicated by a recurved crescentic margin; an inconspicuous curved anterior border, as shown in Figure 37.

Distribution. — Apparently known from southeastern Canada, nearly the whole eastern seaboard and westward through the northern states to Nebraska. Collected in Michigan only at three localities, which are in Calhoun County.

Hentzia palmarum (Hentz)

(Figures 38–43)

Epiblemum palmarum Hentz, 1846.
Anoka palmarum Peckham, 1894.
Icius palmarum Emerton, 1902.
Wala palmarum Peckham and Peckham, 1909.

Male. — Length about 4.2 mm. Legs, 1423; first pair much the longest, scantily fringed with black hairs ventrally on femora and patellae; other legs all of about the same length; with no long white hair on palps and chelicerae. Anterior tibiae with three pairs of ventral spines; first and second pairs of metatarsi with two pairs of ventral spines. Second tibiae apparently with a pair of terminal ventral spines and only one other, on retromargin near the middle, but one or more of these may be lacking. Carapace of moderate height, considerably flattened dorsally, well rounded laterally, longer than

wide in ratio of about 73 : 56. Eye region wider than long in ratio of 23 : 15, middle eyes slightly closer to ALE than to PLE. Eyes occupy about two fifths of length of carapace. Chelicerae more or less porrect, developed, and flattened dorsally. Fang groove with a pair of slender promarginal teeth, the inner of which is very small, and a single retromarginal tooth, which sometimes shows signs of fissidentation (Figs. 40–41). Fang long, slender, and sinuous. Palp: patella somewhat longer than body of tibia without the apophysis (Figs. 38–39); not broader distally than farther back; tube of bulb not so sinuous as in *H. mitrata* and less conspicuous; apophysis long and slender and somewhat curved ventrally. Color: first pair of legs, chelicerae, lip, sternum, and all but the cymbium in the palp a reddish brown; palpal cymbium and all legs except first pair a yellowish white; carapace entirely reddish brown, except for a lateral white stripe on each side, which continues across clypeus to unite on opposite side; a broad reddish central abdominal stripe from base to anal tubercle; on each side of reddish stripe is a whitish stripe with reddish dots; elsewhere abdomen is light reddish.

Female. — First pair of legs not so much elongated as in the male; much the stoutest. Spines essentially as in male. Chelicerae not porrect and not developed as in the male. Fang groove with two promarginal teeth, inner one very small; retromarginal tooth distinctly fissidentate (Fig. 43). Epigynum: two small depressions less than a diameter of one of them apart; a recurved crescentic margin bounding the central opening and a coniform tube leading inward (Fig. 42). Color: differs from that of male considerably; all legs and palpi light yellowish; chelicerae, lip, maxillae, and sternum same as in male; carapace lighter in ocular area and without lateral white stripes; otherwise as in male. Abdomen with a central light reddish stripe much spotted with whitish; dorsolateral whitish stripes much dotted with reddish.

Distribution. — Reported from entire eastern seaboard of the United States; among the northern states westward to Oklahoma and Nebraska. Collected in Michigan only a few times, in Calhoun and Jackson counties.

Genus HYCTIA Simon, 1876

Long slender body, with first pair of legs much the stoutest and longest. Cephalothorax long, low, flat, and narrow, nearly twice as

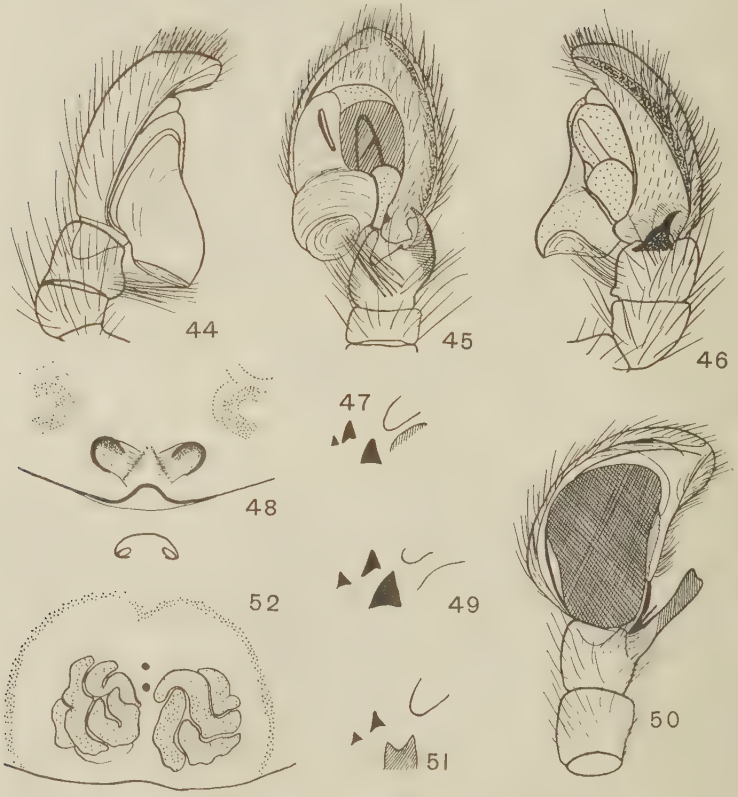
long as wide; lateral sides vertical, nearly parallel, widening just a little behind PLE. Quadrangle of eyes one fourth wider than long, equally wide in front and behind, occupies from one third to two fifths of length of carapace. PME about midway between anterior and posterior rows. Posterior eyes nearly as wide as carapace at that level. Labium longer than wide. Chelicerae vertical and each with a single retromarginal tooth. Sternum oval and contracted in front, where anterior coxae are separated by less than width of labium. Only one species so far taken in Michigan, but *H. pikei* Peckham should be here, it would seem; collected from five localities in Calhoun and Branch counties.

Hyctia bina Hentz

(Figures 44–49)

Attus binus Hentz, 1845.
Menemerus binus Emerton, 1891.
H. bina Peckham and Peckham, 1909.

Male. — Length about 5.75 mm. Legs, 1432; without fringes; other features generic. Spines: anterior pair of tibiae with four pairs of ventral spines, third pair offset laterally; second pair of tibiae ordinarily with a pair of terminal ventral spines and two others along retromargin, but none to match them along promargin. First and second metatarsi each with two pairs of ventral spines. Cephalothorax widest some distance posterior to third row of eyes; about two thirds as wide as long. Eyes occupy almost one half of length of carapace. Ocular area about four fifths as long as wide, almost as wide behind as in front. Third row of eyes occupy slightly more than five sixths of width of carapace. Fang groove with a single stout retromarginal tooth and two smaller promarginal teeth, of which the inner is very small (Figs. 47, 49). It is commonly stated that two forms of the male exist, but only one has been found in Michigan. Palp: patella about equal in length to that of tibia, viewed dorsally; bulb much swollen; a deep curved retrolateral excavation along whole length of cymbium; a stout apophysis turned toward cymbial excavation; embolus arises near base and extends prolaterally more than halfway around margin of bulb (Figs. 44–46). Color: first pair of legs much the darkest; all femora with three dorsal stripes, a median dark-brown one between two much lighter ones; anterior tibiae similarly striped; carapace generally a rich mahogany brown,



EXTERNAL ANATOMY OF SPIDERS

(Figures 44–52)

44. *Hyctia bina*, male palpus, prolateral view
45. *H. bina*, male palpus, ventral view
46. *H. bina*, male palpus, retrolateral view
47. *H. bina*, left male cheliceral teeth
48. *H. bina*, epigynum
49. *H. bina*, left female cheliceral teeth
50. *Maevia vittata*, male palpus, ventral view
51. *M. vittata*, left male cheliceral teeth
52. *M. vittata*, epigynum

with irregular black pencil marks, ocular area darker; a narrow black marginal line, which extends across the very low clypeus, also a narrow white line just dorsal to the black one, but this is complete only at posterior lateral angles; a spot of white hairs above and between AME, more or less white hair dorsal to and behind ALE; a spot of white on each side just posterior to PLE and another on each side just at beginning of posterior declivity. Abdomen: a dark-brown band at base; a band of white just dorsal to the dark band; behind these are three pairs of whitish spots bounding a brownish central area more or less broken by light-colored recurved chevrons; postabdomen also nearly white; laterally many narrow light and dark stripes alternating; ventrally a narrow dark central stripe widened at its two ends, bounded by wider yellowish stripes.

Female. — Length about 7.0 mm. Legs as in male. Spines as in male except that on second tibiae there are ordinarily two pairs of matched ventral spines, with one other unmatched on retromargin. Color: considerably different from that of male. First pair of legs dark without stripes; other legs yellowish; carapace much like that of male, but white spots are lacking; much long white hair on low clypeus; considerable bronze iridescence on ocular area; abdomen with an irregular central light stripe and a reddish-brown stripe on each side of the central one; laterally yellowish dotted with dark brown; a central ventral dark-brown stripe and dots. Epigynum: small, with a central notch and two small depressions (Fig. 48).

Distribution. — Along the eastern coastal states from New England to South Carolina; westward through the northern states to Nebraska. Collected in Michigan only in Calhoun County, in the vicinity of Albion.

Genus MAEVIA C. L. Koch

Cephalothorax moderately high, with sides nearly vertical, parallel in front and then widened a little behind; cephalic part a little inclined as far as PLE and then gently arched back to posterior declivity. Ocular region occupies two fifths of length of carapace, slightly wider in front than behind, about one third wider than long. PME about midway between ALE and PLE; third row occupies about nine tenths of width of carapace at that level. Legs rather slender, first pair only slightly the stoutest. Fang groove with a single retromarginal fissidentate tooth.

Maevia vittata (Hentz)

(Figures 50–52)

Attus vittatus Hentz, 1845.
A. niger Hentz, 1845.
M. vittata Emerton, 1891.
M. vittata Peckham and Peckham, 1909.

Male. — Length about 6.0 mm. Legs, 4132; without fringes. In addition to the generic characters: first pair of tibiae with four pairs of ventral spines, third pair displaced laterally; second pair of tibiae with essentially the same spination as the first, but one or more of the ventral spines may be missing; first and second pairs of metatarsi with two pairs of ventral spines. Carapace only a little widened anywhere, but widest between second and third coxae; longer than wide in ratio of 45 : 28. Fang groove with two small promarginal teeth in addition to the one large retromarginal fissidentate tooth (Fig. 51). Palp: well fringed with black and white hairs, especially on the femur, tibia, and tarsus; patella about as long as body of tibia; tarsus large, broadly curved prolaterally and distally; tibial apophyses much more complex than usually figured; main one is a stout spur, between this and bulb is a thin blade, and from ventral distal surface there extends a low blunt tubercle (Fig. 50). Color: there are two color varieties; the one called *M. niger* (Hentz) has legs of pale yellow; most of the palp is black dorsally except the femur, which is striped white and black; carapace generally a dark irregular brown except for a lighter central thoracic spot divided longitudinally by a dark line; from the area bounded by PME and PLE protrude three large tufts of nearly erect somewhat procurved black hairs; abdomen dark brown with light dots and a series of four or five light dorsal chevrons. The light variety has legs with numerous black dots, rings, and stripes; dorsally the palps are light yellowish, but there are black irregular prolateral stripes; there are no black hair tufts on the head, and the whole carapace is of a lighter color; abdomen like that of dark variety except that it is lighter. In life color more as described by the Peckhams (1909).

Female. — Length about 7.0 mm. Similar to male except for color. Color: appendages light yellowish, with considerable short black hair and a few very small dark spots; carapace nearly black immediately surrounding eyes, but the interocular area much lighter, elsewhere yellowish with much dark hair, a black narrow marginal

pencil line extends on each side from posterolateral angle to opposite PME; abdomen with a broad irregular light central stripe, with increasingly darker chevrons toward posterior half; on each side of the light central stripe is a reddish-brown irregular area; laterally abdomen is yellowish, with small dark dots; ventrally the same except that dark dots are lacking in center. Epigynum: a slightly swollen area with a small depression far anterior; just in front of genital furrow body of epigynum shows two irregularly coiled tubules (Fig. 52).

Distribution. — Known from the entire United States; probably also occurs in southern Canada and, perhaps, in Mexico. Very common in Michigan, where I have collected it from many localities in both peninsulas.

Genus MARPISSA C. L. Koch

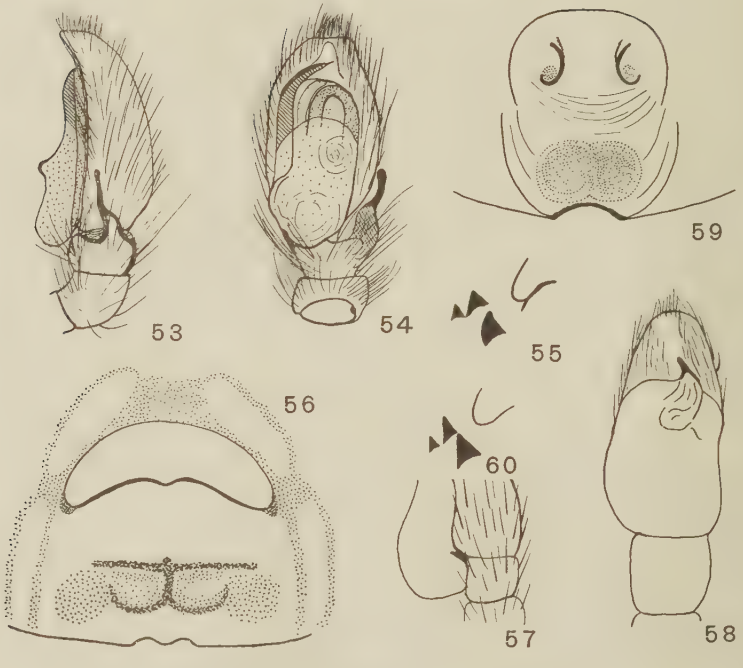
Cephalothorax well rounded in anterior half; wide, flat, and low, widest a little distance behind posterior row of eyes. Ocular region occupies a little less than one half of total length of carapace, only a little wider than long, equally wide in front and behind, middle row of eyes slightly closer to ALE than to PLE. Anterior row recurved as seen from in front; diameter of AME about twice that of ALE. Posterior eyes occupy about seven tenths of width of carapace at that level. Retromargin of fang groove with a single stout simple tooth. Sternum narrowed in front, where anterior coxae are separated by the width of the labium, which is about as wide as long. Legs usually 1423 in males and 4132 in females. Three pairs of ventral spines on first and second tibiae, two pairs of ventral spines on first and second metatarsi, also an extra spine promarginally offset between second and third ventral on first tibiae (some would consider this a prolateral spine). The genus *Marpissa* is well known from the American tropics, where several species abound. Only one species in our northern fauna.

Marpissa undata (De Geer)

(Figures 53–56)

Aranea undata De Geer, 1778.
Marptusa familiaris Peckham, 1888.
Marpissa familiaris F. Cambridge, 1901.
M. rupicola Banks, 1892.
M. undata Peckham and Peckham, 1909.

Male. — Length about 8.4 mm. Legs, 1432; first pair of legs somewhat fringed on femur and patella. Spines generic. Carapace



EXTERNAL ANATOMY OF SPIDERS

(Figures 53–60)

53. *Marpissa undata*, male palpus, retrolateral view
54. *M. undata*, male palpus, ventral view
55. *M. undata*, left male cheliceral teeth
56. *M. undata*, epigynum
57. *Metaphidippus canadensis*, part of male palpus, retrolateral view
58. *M. canadensis*, male palpus, ventral view (redrawn from Fig. 2D, Pl. XXXVI, Peckham, 1909).
59. *M. canadensis*, epigynum
60. *M. canadensis*, left female cheliceral teeth

with generic features. Fang groove with two promarginal teeth in addition to large simple retromarginal tooth (Fig. 55). Palp: well fringed with black and white hairs on femur, patella, tibia, and tarsus; femur with a ventral proximal tubercle, strongly curved and somewhat excavated ventrally; patella dorsally about as long

as tibia; tibial apophysis a long spur, stout basally, attenuated and sinuous through distal half; tarsal bulb swollen proximally, with a tubercle about midway on prolateral side (Figs. 53 54). Color: all legs brownish, with irregular brown and yellowish spots; carapace with a broad nearly black marginal stripe narrowing to disappearance at clypeus, elsewhere grayish, with a darker patch including ocular area, but this is partly due to fact that gray hairs are easily brushed off. A fringe of erect whitish hair below eyes laterally. Clypeus covered with long whitish hair. Abdomen with a broad central light-colored deeply indented stripe from base to anal tubercle; border of light stripe nearly black; lateral sides dark brown, with venter almost black.

Female. — Length about 11.2 mm. Like male in general except for color. Color: legs much lighter-colored than in male, all legs with a good deal of long whitish hair, especially first pair; palps likewise; carapace with narrower dark marginal stripes and larger and lighter dorsal and lateral areas; only regions immediately around eyes dark; much long whitish hair on clypeus. Abdomen like that of male, but all regions lighter-colored. Epigynum: rather large, with anterior recurved crescentic groove, followed posteriorly by a large slightly swollen area (Fig. 56).

Distribution. — Appears to occur throughout the United States and southward through Mexico and much of Central America. Collected from a few localities only, in Cheboygan, Calhoun, and Jackson counties, in the Southern Peninsula of Michigan.

Genus METAPHIDIPPUS F. Cambridge

This genus was established with no adequate definition on the basis of the author's study of Central American species. Cambridge stated that about the only tangible difference between *Metaphidippus* and *Paraphidippus* is the absence of fringes of hair beneath or at sides of first and second legs in the former. Both genera are rather commonly accepted by aranéologists, but no good definitions have been given for either; the status of both here in the north is in doubt. The species included in *Metaphidippus* are generally smaller than those included in *Paraphidippus*. I have a large number of species from Panama which seem to fall into these genera, and it is hoped that some clarification of the confusion surrounding them may be

given when I have opportunity to study them adequately. The following features of *Metaphidippus* may be tentatively stated:

Small spiders, or of moderate size; Michigan species seldom exceed 6 mm. Carapace high, moderately convex dorsally and laterally, widest about opposite second coxae, highest at posterior eyes; a little wider below than above, only moderately robust. Anterior row of eyes recurved, AME larger than ALE in ratio of 16 : 7; AME close together, separated by about one eighth of diameter; eyes of second row somewhat nearer to ALE than to PLE. Ocular region occupies about four ninths of length of carapace; wider than long in ratio of 57 : 40; a little wider behind than in front. Body only moderately hairy and legs seldom with enough hair to be regarded as fringed. First pair of legs enlarged only a little. Chelicerae only moderately enlarged in males.

KEY TO THE SPECIES OF *METAPHIDIPPUS*

MALES

1. Anterior end of tarsal bulb terminating in a long stout distally blunt proximally broad spine (Fig. 70); abdomen with five pairs of dorsal black spots (first pair usually obscure) ..... *M. montanus*, p. 176
1. Tarsal bulb without long stout distally blunt proximally broad spine; ordinarily without five pairs of dorsal abdominal black spots 2

2. Anterior end of tarsal bulb with short sharply pointed spine; abdomen with three black ventral stripes (median one very narrow), and four nearly white ventral ones ..... *M. canadensis*, p. 171
2. Tarsal bulb and abdominal stripes unlike those above 3

3. Tarsal bulb terminating in a pair of long slender spines; carapace without two definite dorsolateral white stripes from ALE to near posterior margin ..... *M. flavipedes*, p. 174
3. Tarsal bulb terminating in a single thin broad somewhat twisted spine with black margin; carapace with two definite dorsolateral white stripes from near ALE to close to posterior margin ..... *M. capitatus*, p. 172

FEMALES

1. First two pairs of legs with black prolateral stripes; second ventral retromarginal tibial spine lacking on first pair of legs ..... *M. flavipedes*, p. 174
1. First two pairs of legs without black prolateral stripes; almost always with three complete pairs of central tibial spines on first pair of legs 2

2. First pair of legs considerably thickened; first tibia with three pairs of long stout spines, the longest of which are as long as or longer than diameter of segment ..... *M. canadensis*, p. 171
2. First pair of legs not unusually thickened; first tibia with shorter and weaker spines, none as long as diameter of segment 3

3. Abdomen with five pairs of definite dorsal dark spots (first pair often obscure); carapace distinctly swollen laterally behind posterior eyes; legs generally yellowish without reddish spots ..... *M. montanus*, p. 176
3. Abdomen generally with no paired definite dorsal dark spots; carapace not swollen laterally behind posterior eyes; legs generally with many reddish spots, often annulations ..... *M. capitatus*, p. 172

Metaphidippus canadensis (Banks)

(Figures 57–60)

Icius canadensis Banks, 1897.
Dendryphantes canadensis Peckham and Peckham, 1909.

Male. — The male of this species has not yet been collected in Michigan, and I have been unable to borrow a specimen for study. The Peckhams (1909) described the male as very closely resembling the female in all essentials. Palp: tibia and patella both short, with the latter somewhat the longer; tibial retrolateral apophysis a short pointed spur; embolus a short pointed spine (Figs. 57–58).

Female. — Length about 5.5 mm. Legs, 4132; first pair much the stoutest, with coxae, femora, and tibiae considerably thickened. Spines on first legs robust and elongated; first leg with three pairs of ventral tibial spines; second legs with one ventral tibial spine, almost in middle of segment; both first and second legs have two pairs of ventral metatarsal spines. Posterior row of eyes wider than anterior row in ratio of 38 : 31; eye space occupies about seven fifteenths of length of carapace, which is longer than wide in ratio of 74 : 55; posterior eyes occupy nearly full width of carapace at that level; middle eyes small and closer to ALE than to PLE in ratio of 9 : 13. Fang groove with a single fairly stout retromarginal tooth and two smaller promarginal teeth, the inner of which is much the smaller (Fig. 60). Color: first pair of legs and chelicerae a deep amber, other legs and palps a much lighter amber; whole ocular area black, with remainder of carapace a reddish brown with a scanty covering of short white hair. A narrow basal abdominal band extends for some distance along lateral sides; dorsum a golden brown, with a series of irregular paired black spots and chevrons along the middle; near beginning of posterior quarter a pair of small white spots and farther back another pair of smaller white spots, anal tubercle also white; lateral sides obliquely, brokenly, and narrowly striped; venter with two nearly black stripes somewhat converging posteriorly and a very narrow central stripe between the two wider ones (see the Peckhams'

Figs. 2 and 2A, Pl. XXXVI, 1909). Epigynum: notch in posterior border not so deep as in many species; just anterior to notch are two conspicuous spermathecae closely crowded together; still further anterior is a well-defined shallow depression with a distinct curved anterior border (Fig. 59).

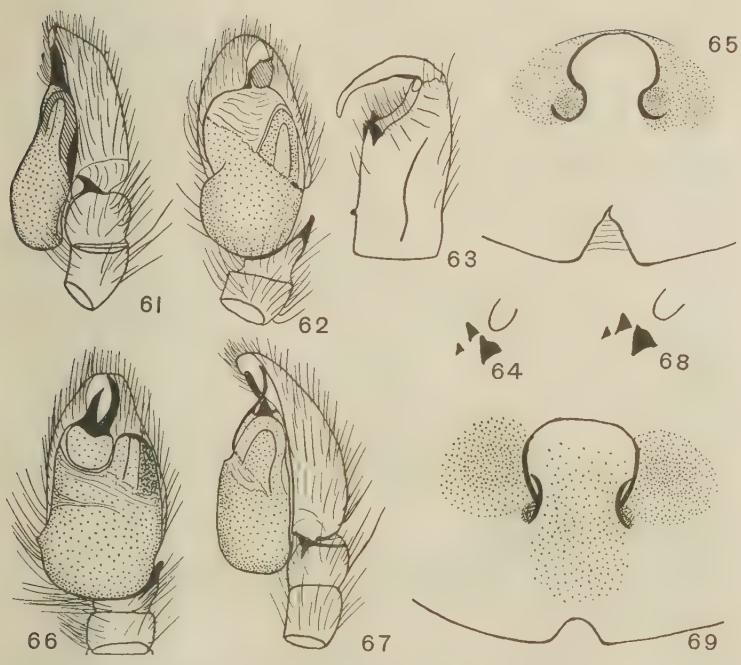
Distribution. — Known from Ottawa, Canada, North Carolina, New England, and now Michigan. Apparently nowhere common. Collected only once in Michigan; Albion, Calhoun County, September, 1932.

Metaphidippus capitatus (Hentz)

(Figures 61–65)

Attus capitatus Hentz, 1845.
Dendryphantes capitatus Peckham, 1888; Peckham and Peckham, 1909.
Metaphidippus capitatus F. Cambridge, 1901.

Male. — Length about 3.8 mm., with considerable variation in size of different individuals. Legs, 1423. Spines: first pair of legs with three pairs of ventral tibial spines, but those along promargin occupy only about the distal half, whereas those along retromargin occupy fully two thirds of length of segment; all relatively weak; second pair of legs with one pair of terminal ventral tibial spines and two more farther back on retromargin with none to match them on the promargin. Distal outer corners of maxillae drawn out into distinct hooks. Posterior row of eyes a little wider than anterior row. Eye space occupies two fifths of length of carapace, which is longer than wide in ratio of 25 : 16. Posterior eyes occupy fifty-five sixty-fourths of width of carapace at that level. Fang groove with a single fairly stout retromarginal tooth and two small promarginal teeth (Fig. 63). Palp: patella somewhat longer than body of tibia (dorsal view); tibia with usual small pointed retrolateral apophysis; tarsal bulb swollen basally, with a simple tubular loop, and terminating distally in a simple, thin, somewhat membranous spine with black margins (Figs. 61–62). Color: first coxae usually reddish brown, all others yellowish; all legs generally ringed with reddish brown; palpal femora white dorsally; carapace a rich reddish-brown, with a white stripe on each side extending from ALE beneath posterior eyes to posterior declivity, usually a short white stripe extending from clypeus just above the margin to opposite PLE, more or less white also around clypeus and AME. Abdomen with a reddish-brown (frequently



EXTERNAL ANATOMY OF SPIDERS

(Figures 61–69)

61. *Metaphidippus capitatus*, male palpus, retrolateral view
62. *M. capitatus*, male palpus, ventral view
63. *M. capitatus*, left male chelicera, retrolateral view
64. *M. capitatus*, left female cheliceral teeth
65. *M. capitatus*, epigynum
66. *Metaphidippus flavipedes*, male palpus, ventral view
67. *M. flavipedes*, male palpus, retrolateral view
68. *M. flavipedes*, left male cheliceral teeth
69. *M. flavipedes*, epigynum

bronzed) central oval area, within which are often four pairs of more or less obscure round spots; bounding this area is a white margin varying greatly in different individuals; ventrally abdomen usually with a broad central reddish stripe bounded laterally by whitish stripes.

Female. — Length about 5.1 mm., with great variation in size

among different individuals. Legs, 4123; first pair somewhat stouter than others. Spines: weaker but essentially like those in male on first legs, except that they occupy a greater part of length of segment; ventral spines of second tibia like those of male except one fewer on retromargin. No hooks on outer distal corners of maxillae. Other features essentially as in male (Fig. 64). Color: all coxae light ventrally, first a little darker; all appendages spotted, ringed, and incompletely striped with reddish brown; carapace nearly black immediately around eyes, elsewhere reddish brown, with many white scales, which are easily removed by handling; abdomen with a dorsal shield-shaped area surrounded by a yellowish area; both areas highly variable in different individuals; shield sometimes more or less broken into a series of paired spots; laterally there is a series of oblique spots narrowly divided by alternate yellowish and reddish-brown stripes; ventrally there is a broad reddish central stripe bounded by yellowish areas; in some individuals this stripe may be broken into two yellowish stripes and three reddish ones. Epigynum: a deep central posterior notch; just anterior to notch is a somewhat raised area; still farther anterior is a recurved chitinous margin enclosing a shallow depression (Fig. 65). In the epigynum great variations have been noted that are due, apparently, to differences in age.

Distribution. — Probably flourishes over much of southern Canada; known from most of the United States and Mexico. One of our most common Michigan Salticidae; collected from many localities in both peninsulas. Females often confused with females of *P. marginatus.*

Metaphidippus flavipedes (Peckham)

(Figures 66–69)

Dendryphantes flavipedes Peckham, 1881; Peckham and Peckham, 1909.

Male. — Length about 4.4 mm. Legs, 1423; first pair somewhat the stoutest. First pair of tibiae with three pairs of ventral spines, retromarginal set occupy about three quarters of length of segment; second pair of tibiae with one pair of terminal spines and usually two more unmatched along retromargin, but either of these may be lacking; first two pairs of metatarsi with two pairs of ventral spines. Outer distal corners of maxillae with small and obscure hooklike extensions. Posterior row of eyes wider than anterior row in ratio of

14 : 13; eye space occupies eight seventeenths of length of carapace, which is longer than wide in ratio of 18 : 13. Posterior eyes occupy twenty-six thirty-firsts of width of carapace at that level. Fang groove with usual single stout retromarginal tooth and two smaller promarginal teeth, the inner of which is very small (Fig. 68). Palp: patella somewhat longer than body of tibia; tibia with usual short pointed ventrally curved apophysis; bulb swollen basally, terminating in an apophysis which is basally broadened and extended into two slender spines curved toward each other (Figs. 66–67). Color: all legs generally light yellowish dorsally, with few light reddish spots and annulations; first two pairs of legs with a single nearly black prolateral stripe on femora, patellae, and tibiae, sometimes on other legs also; a soft white fringe on first legs extending from femora to metatarsi. Carapace with three spots of white scales, two above ALE and extending between ALE and AME, and one between AME; remainder of ocular area and back over posterior declivity to margin a rich reddish brown characteristic of this genus, but also with many white scales; lateral sides with (1) a white marginal stripe from AME to posterior lateral corners, (2) another white stripe from ALE to posterior declivity, and (3) a reddish-brown stripe between the two white ones. Abdomen with a basal white band, which extends dorsolaterally into a stripe on each side to enclose large reddish-brown area, within the posterior half of which in some individuals appear several chevrons and darker spots; venter typically shows three centrally placed reddish stripes separated and bounded by four light ones.

Females. — Length about 4.7 mm. Legs, 4132. Spines weaker but essentially like those in male along ventral surfaces of first two pairs of tibiae and metatarsi. Teeth along fang groove essentially as in male. Color: legs with much more color than in male; prolateral stripes less well defined, but usually occur on all legs; distal ends of all segments more or less reddish brown; carapace generally a rich reddish brown, with white scales irregularly distributed throughout; clypeus white, and the same white cephalic spots occur in the vicinity of eyes as in male except that they are smaller; no definite lateral stripes like those in male; dorsum of abdomen light reddish brown, with many narrow stripes and streaks; on posterior half are several incomplete chevrons and four pairs of darker spots much less distinct than those in *M. montanus*. Venter usually with three reddish stripes and four yellowish ones as in

male. Epigynum: with a fairly deep broad posterior notch; anteriorly there is a fairly well defined recurved margin, which is low anteriorly in the middle; a short excurved fold on each side, where the recurved margin ends (Fig. 69).

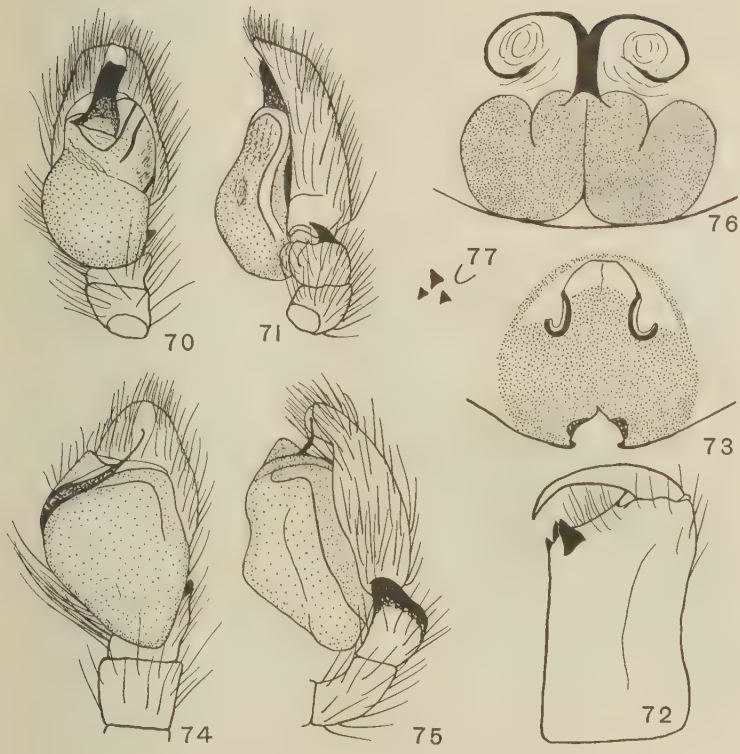
Distribution. — Known from Labrador; probably occurs widely in Canada. Known from New England north of Connecticut and from the northern Middle Western states. Collected in Michigan from many localities in both peninsulas.

Metaphidippus montanus (Emerton)

(Figures 70–73)

Dendryphantes montanus Emerton, 1891.
D. montanus Peckham, 1900; Peckham and Peckham, 1909.

Male. — Length about 3.8 mm., with considerable variation noted among different individuals. Legs, 1423; first pair somewhat thickened, especially the femora. Spines: first pair of tibiae with three pairs of ventral spines, a long interval between second and third on retromargin; second pair of tibiae apparently with a pair of terminal ventral spines and two others along retromargin, but there may be three others and one or more on promargin and probably other variations in some individuals. Apparently the usual two pairs of ventral spines on first and second metatarsi. Outer distal angles of maxillae extended somewhat but not into hooklike structures. Posterior row of eyes only slightly wider than anterior row. Eye space occupies slightly less than half of length of carapace, which is longer than wide in ratio of 83 : 61. Posterior eyes occupy almost five sixths of width of carapace at that level. Fang groove with usual stout retromarginal tooth and two smaller promarginal teeth (Fig. 72). Palp: patella somewhat longer than body of tibia (viewed dorsally), which has a short slender pointed apophysis; tarsal bulb most swollen near middle, and it terminates in a stout elongated squarely truncated spine (Figs. 70–71). Color: all coxae light-colored, first somewhat darker; all pedal femora light yellowish proximally and distally but dark centrally except on ventral surface, no distinct stripes; other segments somewhat annulated and spotted with reddish brown; palpal femur white, more distal segments all reddish brown. Carapace generally a rich reddish brown, with a distinct white stripe on each side extending from ALE below posterior eyes to posterior declivity; with a little white color dorsal to first row of eyes and especially above



EXTERNAL ANATOMY OF SPIDERS

(Figures 70–77)

70. *Metaphidippus montanus*, male palpus, ventral view
71. *M. montanus*, male palpus, retrolateral view
72. *M. montanus*, left male chelicera
73. *M. montanus*, epigynum
74. *Neon nellii*, male palpus, ventral view
75. *N. nellii*, male palpus, retrolateral view
76. *N. nellii*, epigynum
77. *N. nellii*, left female cheliceral teeth

and between AME; elsewhere carapace is a rich reddish brown; abdomen with a whitish basal band, which is continued dorsolaterally, but there is broken by a series of oblique whitish narrow bands, dorsally a large oval reddish-brown area bearing five pairs of nearly black spots, the first pair obscure and the last pair more or less fused to a single spot; typically the venter has a broad reddish-brown central stripe bounded by two narrow light stripes.

Female. — Length about 4.5 mm. Legs: first pair somewhat stouter than others. Carapace considerably swollen laterally just a little posterior to PLE. Spines: weaker but essentially like those in male, with somewhat more variation indicated. Color: legs and palps nearly uniformly light yellowish, with reddish-brown markings only faintly showing on posterior two pairs of legs. Carapace nearly black immediately around eyes though elsewhere reddish brown, with many white scales but no definite white stripes. Abdomen colored like that of male but less deeply. Epigynum: a deep posterior notch; considerably swollen just anterior to genital furrow; farther anterior a low recurved margin within which occurs a second margin also recurved and terminating on each side in a shallow depression with excurved margins (Fig. 73). I do not see the epigynum as it was figured by the Peckhams (1909).

Distribution. — Known from a few localities in New England, southward to North Carolina; from a few localities in the Midwest. Collected in Michigan only twice, both times by R. R. Dreisbach; Midland County.

Genus NEON Simon, 1876

Very small spiders. Carapace high, a little longer than wide; lateral sides nearly parallel; cephalic part gently arched above, thoracic part at first gently declined for a short distance, and then steeply declivitous to posterior margin. Ocular region a little wider than long, about as wide in front as behind, occupies about three fifths of length of carapace. Anterior row of eyes in a somewhat recurved row (viewed from in front); AME slightly less than twice as large as ALE. Second row of eyes equidistant from ALE and PLE. Eyes of third row large and prominent, occupying full width of carapace at that level. Sternum broad in front, widely separating first coxae by more than width of labium, which is a little wider than long.

Fang groove with a single retromarginal tooth and two promarginal teeth, one larger and one smaller than the retromarginal tooth.

Neon nellii Peckham

(Figures 74–77)

Icius obliquus Banks, 1895.

Male. Length about 2.5 mm. Legs, 4132; first pair a little the stoutest. Spines: three pairs of very long and slender ventral spines on first tibiae; two pairs of ventral spines on first pair of metatarsi. Since it is very unlikely that this species will be confused with any other in the state, the descriptive material is reduced to the bare minimum. Palp: patella somewhat longer than body of tibia, which has a very stout short retrolateral apophysis; tarsus large, with bulb swollen medially, and an embolus which extends obliquely across near the distal end and then turns distally near the tip (Figs. 74 75). Color: all legs yellowish, with pale gray spots and prolateral and retrolateral broad gray stripes on anterior legs in well-colored individuals; carapace generally an amber color, the ventral margin with a narrow black line; eyes on black spots; posterior declivity and lateral sides somewhat streaked with black; abdomen yellowish, finely mottled with black or gray dots and a series of chevrons dorsally on posterior half.

Female. Length about 2.9 mm. Legs, 4132. Cheliceral teeth as shown in Figure 77. Other general features so similar to those of male as to deserve no special description. Epigynum: two deep depressions separated by a long narrow rather elevated septum (Fig. 76).

Distribution. Well known from New England, New York, along the Atlantic seaboard to North Carolina; also from several Middle Western states and Washington State; also southeastern Canada. Collected in Michigan at numerous localities in both peninsulas. Probably fairly common in forest débris.

Genus PARAPHIDIPPUS F. Cambridge, 1901

F. Cambridge found it convenient to establish the genus *Paraphidippus* for numerous species among his Central American spiders which appeared to be sufficiently different from other nearly related genera, such as *Phidippus* and *Metaphidippus*. I regard this as a

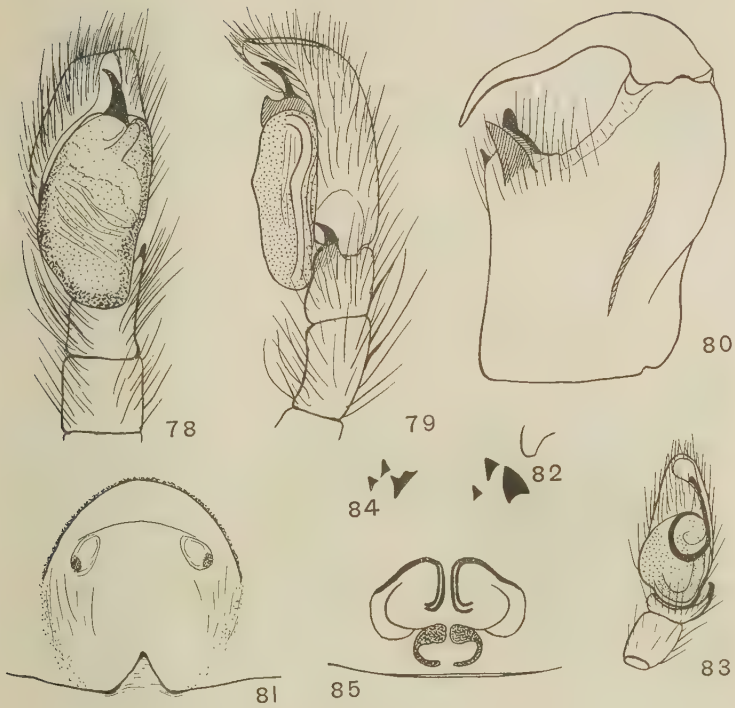
good genus, and it has been recognized by Petrunkevitch (1928) and others. Cambridge placed *Philaeus militaris* Peckham in the genus *Paraphidippus* on the basis of inadequate figures and description. It now appears clear that the species does not belong in *Paraphidippus*, but nobody seems to be sure where it should go. In view of the uncertainty it is provisionally kept in this genus. There is but one species in our fauna, and this can be identified quite readily by its positive characters of palpi and chelicerae.

Paraphidippus marginatus (Walckenaer)

(Figures 78–82)

Attus marginatus Walckenaer, 1837.
A. militaris Hentz, 1845.
Dendryphantes militaris Emerton, 1891.
Paraphidippus militaris F. Cambridge, 1901.
Dendryphantes militaris Peckham and Peckham, 1909.
Phidippus molinor Chamberlin, 1925.

Male. — Length about 5.0 mm., but much variation in size has been noted among individuals. Legs, 1432; first legs much the longest but not much thickened. Spines: first pair of tibiae with three pairs of ventral spines, those on promargin occupy less than one half of length of the segment, those on retromargin occupy about two thirds of length of segment, interval between second and third retromarginal nearly twice as great as interval between first and second; second pair of tibiae with one pair of terminal ventral spines and two more along retromargin. First and second metatarsi with two pairs of ventral spines. Distal outer corners of maxillae produced into very small hooklike extensions. Posterior row of eyes almost exactly as wide as anterior row. Eye space occupies only a little less than one half of length of carapace, which is longer than wide in ratio of 79 : 62. Posterior eyes occupy about five sixths of width of carapace at that level. Chelicerae considerably enlarged (Fig. 80); fang groove deeply excavated; with a very large retromarginal tooth and two promarginal teeth, one of which is large and the other very small. Palp: slender, patella and tibia about equal in length; tibia with a single simple retrolateral, basally stout, terminally slender apophysis; tarsal bulb ends distally in a slender procurved spine (Figs. 78–79). Color: all coxae usually light-colored, with first somewhat the darkest; first femora usually rich reddish brown with white scales, all other femora usually yellowish in proximal halves



EXTERNAL ANATOMY OF SPIDERS

(Figures 78–85)

78. *Paraphidippus marginatus,* male palpus, ventral view
79. *P. marginatus,* male palpus, retrolateral view
80. *P. marginatus,* left male chelicera
81. *P. marginatus,* epigynum
82. *P. marginatus,* left female cheliceral teeth
83. *Peckhamia picata,* male palpus, ventral view
84. *P. picata,* left male cheliceral teeth
85. *P. picata,* epigynum

and reddish brown distally; other segments of legs reddish brown but progressively lighter toward distal segments. Palpal femora with white scales dorsally, also at distal end of patella on dorsal surface; otherwise segments are reddish brown dorsally, lighter beneath.

Carapace a rich reddish brown, with a white stripe from ALE somewhat below PME and PLE back to posterior declivity but not ordinarily farther, many white scales over dorsum, the most persistent of which are in region of longitudinal thoracic groove and midway between PME; clypeus is white, and the white color continues along ventral margin in a very narrow line; all eyes except AME on black spots. Abdomen: at base a light reddish-brown band, which continues on each side as a lateral stripe; just above this is a basal whitish band, which continues dorsolaterally not quite to posterior end; this delimits a bright somewhat bronzed dorsal area, within which is a series of small obscure light-colored paired spots; ordinarily the venter has a broad central dull reddish-brown stripe, with a narrower lighter stripe on each side.

Female. — Length about 6.7 mm. Legs, 1423; first pair the stoutest. Spines on ventral surface of first two pairs of tibiae and metatarsi essentially same as in male. Cheliceral teeth as shown in Figure 82. Color: legs essentially as in male except somewhat lighter; carapace a rich reddish brown all over except for white scales generally distributed and a very narrow ventral white marginal stripe continuous with the clypeus, which is well clothed in white hair. Color of abdomen much like that of male except that areas are less well defined. Four pairs of light spots in dorsal area usually well defined. On the venter the central reddish stripe usually narrower and the lighter bounding stripes usually broader. Epigynum: when mature there is a fairly deep broad posterior notch at the genital furrow; anteriorly there is a narrow recurved margin and two small openings about four short diameters of one of them apart (Fig. 81).

Distribution. — Probably present throughout the United States, through much of southern Canada and northern Mexico. One of our most common jumping spiders throughout Michigan.

Genus PECKHAMIA Simon, 1901

Carapace either fairly low and flat (*scorpionia*) or fairly high and convex (*picata*). Ocular region longer than wide, occupies from one half to two thirds of length of carapace. Anterior row of eyes recurved; AME almost touching one another, at least twice as large as ALE; PME much closer to ALE than to PLE, which are large and and situated near margin of carapace. Chelicerae small, vertical; with a weakly compound retromarginal tooth. Definitely antlike.

KEY TO THE SPECIES OF *PECKHAMIA*

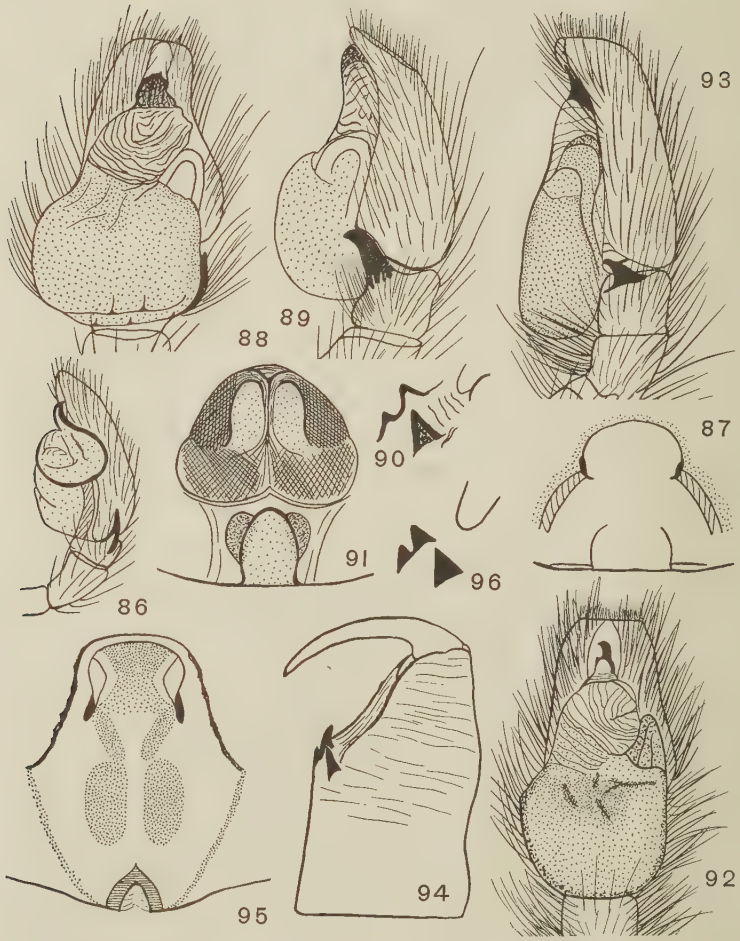
1. Anterior tibiae with three pairs of ventral spines; first legs much enlarged; two white spots in depression behind PLE; carapace fairly high
P. picata, p. 183
1. Anterior tibiae with only one pair of matched ventral spines; first legs only moderately enlarged; carapace without definite white spots, lower and flatter than in *picata* ..... *P. scorpionia*, p. 185

Peckhamia picata (Hentz)

(Figures 83–85)

Synemosyna picata Hentz, 1845.
Synageles picata Peckham, 1888, 1892.
P. picata Simon, 1901.
P. picata Peckham, 1909.

Male. — Length, 3.5 mm. Legs, 4123; first pair much enlarged, especially femora, patellae, and tibiae. Spines: three pairs of ventral spines on first tibiae; second tibiae with a pair of terminal ventral spines and two more unmatched ones along retromargin; first pair of metatarsi with two pairs of stout spines; second pair of metatarsi with two pairs of weak spines. Chelicerae small, vertical, with a small retromarginal compound tooth and two small promarginal teeth (Fig. 84). Posterior row of eyes only slightly wider than anterior row; eye space longer than wide in ratio of 9 : 8; occupies nearly nine seventeenths of length of carapace, which is longer than wide in ratio of 17 : 9; PME nearer to ALE than to PLE in ratio of 1 : 2; posterior eyes occupy ten elevenths of width of carapace at that level. Carapace rises gently to PME, remains nearly level to opposite posterior eyes, where there is a shallow groove, then there is a sharp rise to a low hump, from which the posterior declivity descends steeply at first and then very gently to posterior border. Anterior end of abdomen bulbous and separated from remainder of this part of body by a marked groove; whole dorsum covered by a shield. Palp: delicate; patella about twice as long as tibia, which has a stout spur as its retrolateral apophysis; embolus makes a complete revolution and then extends as a long slender spine nearly to distal end of tarsus (Fig. 83). Color: first pair of legs a deep amber except last two segments, which are yellowish; second pair of legs with dark-brown tarsi and metatarsi, other segments light yellow with black prolateral stripe; other legs amber with prolateral stripes less conspicuous; ocular region a glistening granular black; lateral sides of carapace a



EXTERNAL ANATOMY OF SPIDERS (Figs. 86–96)

86. *Peckhamia scorpionia,* male palpus, retrolateral view
87. *P. scorpionia,* epigynum
88. *Phidippus altanus,* male palpus, ventral view
89. *P. altanus,* male palpus, retrolateral view
90. *P. altanus,* left male cheliceral teeth
91. *P. altanus,* epigynum
92. *Phidippus audax,* male palpus, ventral view
93. *P. audax,* male palpus, retrolateral view
94. *P. audax,* left male chelicera
95. *P. audax,* epigynum
96. *P. audax,* left female cheliceral teeth

rich reddish brown, with three or four large obscure black irregular patches on each side; two white spots close together in the depression just behind the posterior eyes; bulbous anterior part of abdomen a light brown, remainder a rich dark brown; venter almost black, except a yellow patch just posterior to genital furrow.

Female. — Females have not yet been collected in Michigan. The Peckhams (1909) give the following data: length about 4.8 mm.; legs, 4231. Other features essentially like those of male. Epigynum as shown in Figure 85 (taken from specimen in Museum of Comparative Zoölogy at Harvard College).

Distribution. — Believed to be spread throughout the entire United States. Collected only twice in Michigan; Clare County and Emmet County.

Peckhamia scorpionia (Hentz)

(Figures 86–87)

Synemosyna scorpionia Hentz, 1845.
Synageles scorpionia Peckham, 1888.
P. scorpionia Peckham and Peckham, 1909.

Description from specimens collected at Sea Cliff, New York, by Mr. Nathan Banks and loaned by the Museum of Comparative Zoölogy at Harvard College.

Male. — Length, 3.2 mm. Legs, 4123?; first pair somewhat enlarged, especially the femora; anterior tibiae only a little longer than patellae. Spines: anterior tibiae with two pairs of matched ventral spines, an odd one on retromargin, and none terminal; second tibiae seem to have no ventral spines; first and second metatarsi with two pairs of ventral spines each. Chelicerae with a single relatively large retromarginal fissidentate tooth, and probably two small promarginal teeth; mildly concave medially. Anterior row of eyes just slightly wider than posterior row; eye space longer than wide in ratio of about 8 : 7; occupies a little less than two thirds of length of carapace, which is longer than wide in ratio of 33 : 18. PME closer to ALE than to PLE in ratio of 7 : 20; posterior eyes occupy about ten elevenths of width of carapace at that level. Carapace rises very gently to opposite PME, then falls gently to a point opposite PLE, and steeply to about one tenth of its length from posterior margin. Anterior third of abdomen bulbous and separated from remainder by a marked constriction; whole dorsum covered by a shield. Palp: moderately robust; patella nearly twice as long as body of tibia, which has a single stout elongated retrolateral apophysis; embolus makes a complete revolution and ends in a hook (Fig. 86). Color: all legs and palp a deep amber; first legs somewhat

darker than others (only a slight indication of the black stripes mentioned by the Peckhams, 1909); carapace a mahogany brown with eyes on black spots and a few white hairs around anterior row of eyes; also indications of a small median spot of white scales at beginning of posterior declivity, with two smaller white spots lateral to the median one. Abdomen also mahogany brown dorsally, venter much lighter, with lateral sides striped with alternate light and dark lines.

Female. — Length about 3.0 mm. Much like male except in respect to secondary sexual characters. Carapace lower and flatter. Legs generally lighter-colored. Dorsal abdominal shield restricted to dorsal part of bulbous anterior end of abdomen. A white band crosses dorsum at the groove; on venter is also a broad light procurved band just posterior to genital furrow. Epigynum: obscure; a slightly swollen area bounded in front by a recurved margin enclosing a yellowish undifferentiated area; just anterior to the genital groove is another yellowish area partly surrounded by a delicate margin (Fig. 87). I do not see this organ as it was illustrated by the Peckhams, 1909.

Distribution. — Reported from many isolated localities extending over nearly all the United States and southeastern Canada. Collected only once in Michigan; Calhoun County, May, 1935.

Genus PHIDIPPUS C. L. Koch, 1846

Medium to large spiders; usually hairy. Carapace high, robust, wide, and convex laterally. Ocular quadrangle from one third to two thirds wider than long; occupies two fifths of length of carapace or more; wider behind than in front. Eyes relatively small, AME less than twice as large as ALE; PME about half as far from ALE as from PLE, which do not occupy nearly the width of the carapace at that level.

KEY TO THE SPECIES OF *PHIDIPPUS*

MALES

1. Chelicerae with a tubercle on front surface; a central dorsal abdominal somewhat triangular white spot as well as other light spots and bars; palpal bulb terminates in a short beaklike spine springing from a broad base (Fig. 92) ..... *P. audax*, p. 189
1. Not with combination of characters given above 2

2. Chelicerae without a tubercle on front face of basal segment; dorsal region of abdomen with a broad rust-red margin; palpal bulb terminates in a short broad spine (Fig. 88) ..... *P. altanus*, p. 188
2. Not with combination of characters given above 3

3. Abdomen uniformly reddish brown dorsally; first pair of legs with many white hairs; palpal bulb terminates in a stout sickle-shaped spine (Fig. 97) ..... *P. brunneus*, p. 191
3. Not with combination of characters given above 4

4. First pair of legs notably elongated; clypeus without white hairs; abdomen usually with glistening silvery scales and red spots in central stripe; palpal bulb terminates in a slender curved spine of moderate length *P. clarus*, p. 193
4. Not with combination of characters given above 5

5. Clypeus with long white hair; carapace with two broad white dorsolateral stripes; palpal bulb terminates in a somewhat twisted slender spine with a broad base ..... *P. insigniarius*, p. 195
5. Not with combination of characters given above 6

6. Abdomen and carapace reddish dorsally with two or three pairs of small white spots within two dark stripes; palpal bulb terminates in a long uniformly slender spine, which is turned ventrally (Fig. 111) *P. pius*, p. 197
6. Not with combination of characters given above 7

7. Legs and cephalic region unusually hirsute; abdomen with two somewhat indistinct dark stripes, within which are four pairs of whitish spots; palpal bulb with an elongated rugulose area beyond which a short broad spine extends (Fig. 113) ..... *P. purpuratus*, p. 199
7. Legs and cephalic region not unusually hirsute; carapace and abdomen at least partly reddish; palpal bulb with distal rugulose area short and broad, terminating in a spine of moderate length and stoutness *P. whitmanni*, p. 200

FEMALES

1. Epigynum more or less completely separated into right and left halves by a longitudinal septum 2
1. Epigynum not separated into right and left halves by a longitudinal septum 5

2. A large species, about 10 mm.; dorsum of abdomen with marginal red or yellow oblique bars, central region with small glistening scales; epigynum with a deep posterior marginal notch with lateral extension and a shallow depression separated into halves by a well-defined longitudinal septum (Fig. 91) ..... *P. altanus*, p. 188
2. Not with combination of characters given above 3

3. All legs rather light brown; carapace uniformly reddish brown overlaid with white scales; abdomen fairly uniformly light reddish brown; epigynum much longer than wide, with a broad posterior marginal notch and shallow depressed anterior region separated into halves by a nearly suppressed longitudinal septum (Fig. 101) ..... *P. brunneus*, p. 191
3. Not with combination of characters given above 4

4. Carapace brownish, with many whitish hairs; very prominent tufts of black hair between PME and PLE; much whitish hair on palps and clypeus; abdomen with a black median dorsal stripe bifurcated anteriorly to

enclose a white spot, also with yellowish basal band and two bright red marginal stripes ..... *P. insigniarius*, p. 195

4. All legs a reddish brown, palps with much long white hair on last three segments; carapace a reddish brown with many white scales; abdomen a dull brownish dorsally with two median darker stripes usually bearing four pairs of small white spots; epigynum with a deep but rather narrow posterior marginal notch, and centrally with two rather deep depressions separated by a somewhat suppressed longitudinal septum (Fig. 116) *P. purpuratus*, p. 199

5. Abdomen nearly black, with a central dorsal white spot usually followed by two pairs of white bars and more obscure whitish spots; epigynum considerably longer than wide, with a fairly deep-bordered posterior marginal notch and a shallow depression without any median longitudinal septum (Fig. 95) ..... *P. audax*, p. 189
5. Not with combination of characters given above 6

6. All legs more or less darkly annulated; abdomen with two dorsal dark stripes bearing several pairs of small whitish spots; venter usually with a narrow dark central stripe and a broader darker stripe on each side reaching to base of spinnerets; epigynum nearly as wide as long *P. clarus*, p. 193
6. Not with combination of characters given above 7

7. All legs fairly uniformly yellowish; carapace also generally yellowish except black ocular area; abdomen yellowish, with two central dorsal narrow black stripes usually with two pairs of small white spots; epigynum with a broad shallow posterior marginal notch and a scalloped anterior border just behind which are two small shallow depressions (Fig. 112) ..... *P. pius*, p. 197
7. All femora darkened, other segments barred; a light stripe from AME nearly across ocular area; dorsum red, sometimes with white spots; venter usually black, with two light stripes converging to spinnerets; epigynum nearly as wide as long, broadly oval (Fig. 118) *P. whitmanni*, p. 200

Phidippus altanus Gertsch

(Figures 88–91)

Male. — Length about 9.0 mm. Legs, 1423; first pair considerably the stoutest; all legs fringed but none heavily. Spines: first pair of tibiae with three pairs of ventral spines not evenly matched; those on promargin occupy just a little more than half of length of segment whereas those on retromargin occupy about two thirds of length; the second pair of tibiae have one pair of terminal spines and two others on the retromargin not matched by corresponding prolateral spines. First two pairs of metatarsi with the usual two pairs of ventral spines. Distal outer corners of maxillae drawn out into very definite hooklike extensions. Posterior row of eyes wider than anterior row in ratio of 20 : 17; eye space occupies six thirteenths of

length of carapace, which is longer than wide in ratio of 13 : 11; posterior eyes occupy almost four fifths of width of carapace at that level. Fang groove with a single tooth of moderate size on retromargin and two teeth on promargin, the inner of which is very small (Fig. 90). Sternum very convex near posterior end. Palp: patella considerably longer than body of tibia; tibia with a retrolateral spur nearly as long as body and curved only a little toward the bulb, which is swollen at the base, where it is almost quadrilateral; embolus short, stout, irregularly blunt at distal end (Figs. 88 89). Color: legs generally dark brown, with many darker spots and annulations together with white scales; fringe on first patella and a portion of first tibia are partly composed of whitish hairs; palp brownish with a sparse black fringe dorsally and ventrally at proximal end of femur; chelicerae iridescent; carapace dark brown; abdomen with a broad nearly black central stripe, within which are two pairs of short oblique rust-red bars; completely surrounding this central dark stripe is a broad bright rust-red margin (short recumbent hairs); long whitish hairs grow out of this red margin; lateral and ventral surfaces dark brown, with the usual four narrow-beaded light stripes.

Female. — Known only from Dr. Gertsch's original description. Length, 10.5 mm. Color: like that of male except as follows: palps and clypeus with long white hair; legs with more white hair and white scales than male; abdomen with red or yellow dorsal margin around a larger dark central stripe overlaid with shiny black scales. Epigynum: not figured by Dr. Gertsch but said to be like that of *P. ardens;* my Figure 91 was drawn from specimen given by the author of the species.

Distribution. — Described from Yellowstone National Park; also known from Alberta, Saskatchewan, and now from Michigan, but taken in this state only once, in Midland County, by R. R. Dreisbach, May, 1939.

Phidippus audax (Hentz)

(Figures 92–96)

Attus audax Hentz, 1844.
P. tripunctatus Emerton, 1891.
P. audax Peckham and Peckham, 1909.

Male. — Length about 9.6 mm.; great variation in size among different individuals. Legs, 1423; first pair of legs heavily fringed

and somewhat enlarged; others progressively less fringed and less hairy toward last pair. Spines difficult to see because of heavy fringes. Distal outer corner of maxillae drawn out into distinct tubercles. Carapace very broad and blunt anteriorly. Posterior row of eyes wider than anterior row in ratio of 47 : 40; eye space occupies sixteen thirty-ninths of length of carapace, which is longer than wide in ratio of 39 : 31. Posterior row of eyes occupies about three fourths of width of carapace at that level. Chelicerae robust with rugate surface, with prominent tubercle on front face of basal segment near distal end, with a slender retromarginal tooth and two promarginal teeth, the inner of which is very small (Fig. 94). Sternum very convex near posterior end. Palp: very hairy, patella somewhat longer than tibia, which has a small pointed apophysis turned distally toward the bulb, which is swollen basally; the embolus is a stout short hooklike spine (Figs. 92–93). Color: legs generally dark brown or black, more or less streaked with light brown, and with much long hair; first pair of legs with white fringes on prolateral surface of distal end of femora, prolateral side of patellae, proximal end of metatarsi and tarsi, elsewhere fringes are black and gray. Carapace a dark brown; abdomen generally a dark brown with a narrow white basal band, which continues for a short distance dorsolaterally; near middle of dorsum is a white spot, which is frequently somewhat triangular and is continued laterally into white pencil lines; farther back are usually two pairs of narrow bands in a somewhat dorsolateral position, and there may be additional small white spots or bands. Venter usually dark brown, with four obscure narrow-beaded light stripes. Palpal femur has white scales and hair dorsally and the patella only white scales. Chelicerae very iridescent-greenish.

Female. — Length about 11.0 mm., with great variation among different individuals. Legs, 4123; first pair the stoutest; fringed as in male. First tibiae with three pairs of ventral spines, occupying only a little more than one half of length of segment; second tibiae with one pair of terminal ventral spines and two others along retromargin, occupying two thirds of length of segment; first and second metatarsi with two pairs of ventral spines. Fang groove with teeth as shown in Figure 96. No hooks or tubercles on outer distal corners of maxillae. Otherwise essentially like the male except for color. Tufts of long stiff black hair in eye region. Color: basal abdominal band often lacking, as well as one or more pairs of the narrow white

bands behind the central dorsal white spot. Epigynum: longer than wide; a bordered, fairly deep notch in the posterior margin; somewhat depressed in anterior half, where there are small secondary depressions or possibly openings, as shown in Figure 95.

Distribution. — Probably spread over the entire United States and most of southern Canada. Apparently our most common *Phidippus* in Michigan; taken in many localities in both peninsulas.

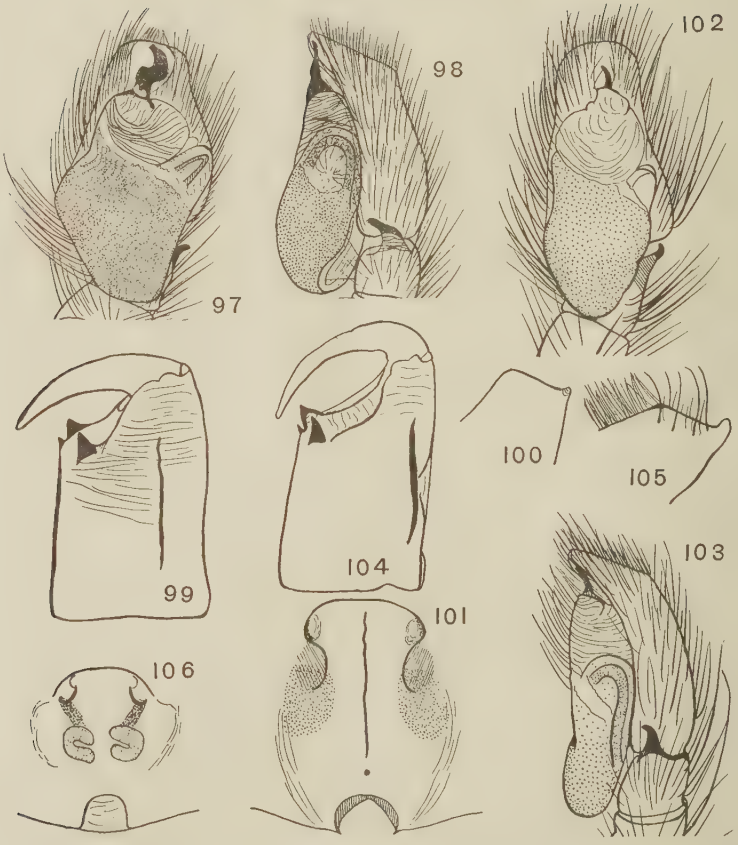
Phidippus brunneus Emerton

(Figures 97–101)

P. brunneus Peckham and Peckham, 1909.

Male. — Length about 7.0 mm. Legs, 1423; first pair the stoutest; all legs with weakly developed fringes, the first most heavily fringed. Spines: as usual except that those of first leg seem to be weaker than usual in other species (mostly broken from my only Michigan male). Maxillae (Fig. 100) with mildly developed hooks on outer distal corners (hardly more than tubercles). Posterior row of eyes wider than anterior row in ratio of 20 : 17; posterior row occupies four fifths of width of carapace at that level; eye space occupies twenty-three fifty-sixths of length of carapace, which is longer than wide in ratio of 28 : 25. Fang groove with a single simple stout retromarginal tooth and two promarginal teeth, the inner of which is very small (Fig. 99). Palp: patella considerably longer than tibia; tibial retrolateral apophysis short, stout at base, distally tapered and rather strongly curved toward bulb; bulb basally much swollen, terminates in a stout sickle-shaped hook, blunt at distal end (Figs. 97–98). Sternum strongly convex near posterior end. Color: legs all dark reddish brown except dorsally lighter with a narrow median dark stripe, especially on femora; first legs with many white prolateral hairs; chelicerae iridescent-greenish; palps with white scales dorsally on femora and patellae; carapace generally dark brown, with eyes on black areas; abdomen with a narrow whitish basal band, which extends dorsolaterally to about the middle; dorsum entirely covered by a reddish-brown area, which is said to look uniformly red in life. Venter is uniformly brownish except for the usual four narrow-beaded light stripes.

Female. — Length about 10.5 mm. Legs, 4132; first pair considerably the stoutest. Spines essentially as in male. Distal outer



EXTERNAL ANATOMY OF SPIDERS

(Figures 97–106)

97. *Phidippus brunneus*, male palpus, ventral view
98. *P. brunneus*, male palpus, retrolateral view
99. *P. brunneus*, left male chelicera
100. *P. brunneus*, distal end of maxilla
101. *P. brunneus*, epigynum
102. *Phidippus clarus*, male palpus, ventral view
103. *P. clarus*, male palpus, retrolateral view
104. *P. clarus*, left male chelicera
105. *P. clarus*, distal end of maxilla
106. *P. clarus*, epigynum

corners of maxillae not drawn out into hooks. Other features essentially like those in male except the color. Color: all legs light reddish brown, with considerable hair of two kinds, short white scales and mixed long black and white hair; palps with much long white hair and sparse long black hair; chelicerae covered basally with white scales, elsewhere in front rugose and green-iridescent; carapace generally reddish brown overlaid with white scales; long white hairs and a few black ones are generally distributed, with long black hairs crowded somewhat in region of eyes, where whole ocular area is much darker; clypeus with many white scales and some long white hairs; abdomen generally and fairly uniformly light reddish brown dorsally, lighter on ventral surface. Epigynum: with a fairly deep, broad bordered notch in posterior margin; just anterior to notch organ is swollen; still farther anterior is a depression of moderate depth, through which a suppressed longitudinal septum partly divides the depressed area into halves (Fig. 101).

Distribution. — Well known from New England and New York; also known from Michigan and Illinois. Collected in Michigan only a few times and only in the central and southern part of the Southern Peninsula.

Phidippus clarus Keyserling

(Figures 102–106)

P. clarus Keyserling, 1884.
P. insolens Peckham, 1888.
P. multiformis Emerton.
P. clarus Peckham, 1909.
Dendryphantes clarus Petrunkevitch, 1911.

Male. — Length about 7.3 mm. Legs, 1423; first pair much the longest and stoutest, also moderately fringed; other legs lightly fringed. Spines: first pair of tibiae with three pairs of ventral spines, rather weak, those along the promargin occupy considerably less than one half of length of segment, whereas those along the retromargin occupy somewhat more than one half of length of segment; second pair of tibiae with two pairs of ventral spines fairly well matched and another farther back on retromargin; first two metatarsi with two pairs of ventral spines. Outer distal corners of maxillae drawn out into blunt robust extensions (Fig. 105). Posterior row of eyes wider than anterior row in ratio of 7 : 6; eye space occupies twenty-three fifty-eighths of length of carapace, which is longer than wide in ratio

of 58 : 49; posterior eyes occupy five sevenths of width of carapace at that level. Fang groove with a fairly stout retromarginal tooth and two promarginal teeth, the inner and smaller of which is almost a part of the larger one (Fig. 104). Palp: patella considerably longer than body of tibia, which has a simple retrolateral apophysis, which is turned retrolaterally and moderately curved toward the bulb; bulb not greatly swollen in the individuals examined; embolus ends in a short slender hook (Figs. 102–103). Color: all legs a dark reddish brown, with light-colored regions above, within which are narrow darker stripes, especially true of femora; palp with dorsal white scales from femur to base of tarsus; also a fringe, a part of which is composed of long white hairs; carapace very dark brown or black; no white on clypeus; abdomen with a white basal band, which extends laterally only a short distance; from basal band a broad central dark stripe extends to spinnerets; central stripe usually with silvery scales and three pairs of red spots in posterior two thirds; on each side of central stripe is a dorsolateral stripe covered with short light hair, which looks reddish in older specimens and grayish in younger ones; abdomen ventrally dark-colored, with four faint narrow light stripes.

Female. — Length about 10.0 mm. Legs, 4132; first pair considerably the stoutest; all with sparse fringes, somewhat more ample on first. Ventral spines on first tibiae and metatarsi like those of male; second metatarsi with ventral spines like those of male, but ventral spines on tibia very irregular even on the right and left sides of the same individuals. No hooks on outer distal corners of maxillae. Color: legs like those of male, except that they are lighter; first legs and palps with a good deal of white hair; carapace a rather bright reddish brown (appears quite reddish in life), much darker on ocular region; a sparse covering of short light hair and long light hair, especially at the lateral sides; the abdomen in my Michigan specimens is usually a fairly uniform reddish gold except for two faint darker central stripes, within which appear a few pairs of small white spots; the venter almost always shows a narrow central dark stripe reaching back about two thirds of length and two other broader and darker stripes reaching to base of spinnerets and meeting there. Epigynum with features shown in Figure 106.

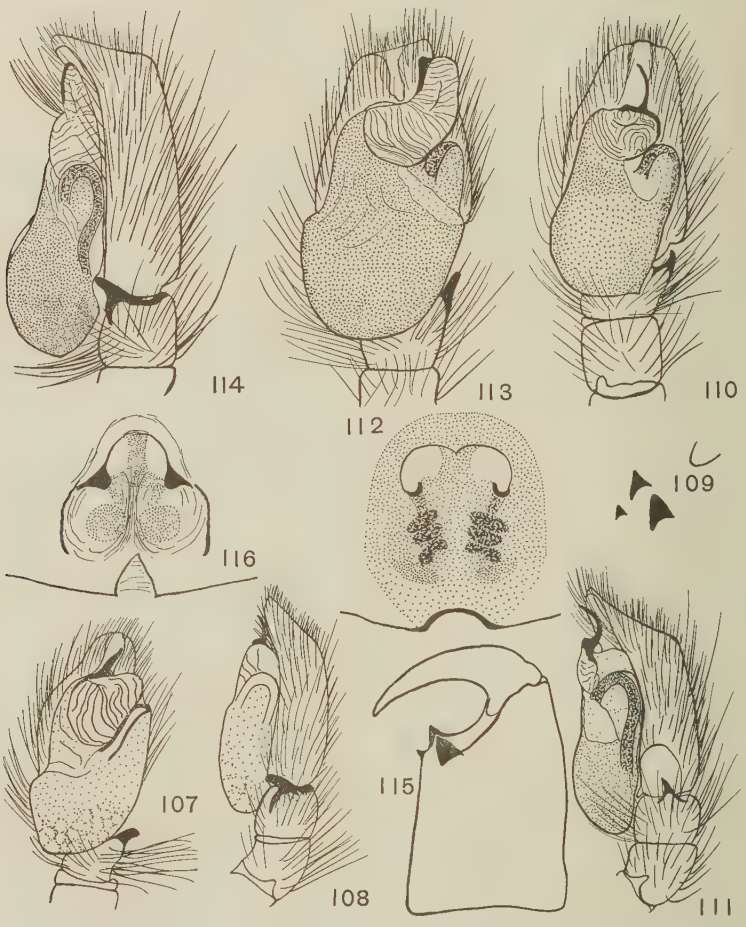
Distribution. — Probably distributed throughout most of the United States; fairly common throughout southern Michigan, but not yet collected in the Northern Peninsula.

Phidippus insigniarius C. L. Koch

(Figures 107–109, 126)

P. insigniarius Banks, 1907.
P. insigniarius Peckham and Peckham, 1909.

Male. — Length about 6.7 mm. Legs, 1423; first pair well fringed with white hairs; others similarly fringed but less amply. Spines: first tibiae with three pairs of ventral spines of moderate size; on prolateral side spines occupy less than one half of length of segment, and on retromarginal side they occupy a little more than one half of segment; second tibiae with one pair of terminal spines and one other on retromargin near middle of segment; first two pairs of metatarsi with two pairs of ventral spines as usual. Outer distal corners of maxillae extended into small blunt apophyses or tubercles. Posterior row of eyes wider than anterior row in ratio of 32 : 27; eye space occupies two fifths of length of carapace, which is longer than wide in ratio of 5 : 4; posterior eyes occupy three fourths of width of carapace at that level. Fang groove with a single simple retromarginal tooth and two promarginal teeth, the inner of which is very small (Fig. 109). Palp: patella considerably longer than tibia; tibia with a retrolateral apophysis, stout at base, pointed and spurlike distally, acutely turned toward bulb, with a greater angle than usual between it and body of tibia; embolus fairly stout at base but somewhat spirally twisted, terminating in a slender process of moderate length (Figs. 107–108). Color: legs all generally dark brown, with lighter dorsal surfaces and narrow dark dorsal stripes irregularly distributed; fringes on legs white, and white scales appear on several segments, most persistently on prolateral and dorsal surfaces of first two pairs of tibiae and metatarsi; carapace dark brown, almost black, with prominent tufts of black hair behind and below PME; chelicerae brightly iridescent-green; clypeus covered with long white hair; two broad lateral white stripes extend from clypeus to posterior declivity, but do not unite there; abdomen has a basal white band, which extends dorsolaterally not quite halfway toward posterior end; generally the whole dorsum is bright reddish brown (red in life); two nearly black stripes extending from the light basal band posteriorly to about the middle, where they unite and then continue as a single stripe with lateral extensions to the anal tubercle. There is thus a dorsal abdominal pattern different from that of any other spider in this genus in Michigan. The ven-



EXTERNAL ANATOMY OF SPIDERS (Figs. 107–116)

107. *Phidippus insigniarius*, male palpus, ventral view
108. *P. insigniarius*, male palpus, retrolateral view
109. *P. insigniarius*, left male cheliceral teeth
110. *Phidippus pius*, male palpus, ventral view
111. *P. pius*, male palpus, retrolateral view
112. *P. pius*, epigynum
113. *Phidippus purpuratus*, male palpus, ventral view
114. *P. purpuratus*, male palpus, retrolateral view
115. *P. purpuratus*, left male chelicera
116. *P. purpuratus*, epigynum

ter has a broad central dark stripe from genital furrow to near base of spinnerets; on each side of the dark stripe is a narrower light stripe; the lateral sides are dark; thus, when the specimen is viewed from the ventral aspect, five rather conspicuous stripes are seen, three dark and two light ones.

Female. — No females yet taken in Michigan. According to Peckham, length varies from 8 to 10 mm. Legs, 4132; first pair fringed as in male. Palp: whole organ covered with long white hairs tinged with red at extremities of patellae and tibiae. Colors of other parts of body seem to be very similar to those of male. Epigynum: not figured by the Peckhams (1909), but said to be very similar to that of *P. johnsoni* (Peckham). During the completion of this paper Miss Elizabeth B. Bryant kindly loaned me for study a specimen of each sex from the collections of the Museum of Comparative Zoölogy at Harvard College. From the female I have drawn the epigynum to show its essential features (Fig. 126).

Distribution. — Known from the Atlantic coastal region from New England to South Carolina; also reported from several Middle Western states, and westward to British Columbia. Some of these records appear to be doubtful. Taken only once in Michigan, by R. R. Dreisbach; Midland County, May, 1941.

Phidippus pius Scheffer

(Figures 110–112)

P. pius Scheffer, 1905.
P. pius Peckham, 1909.

Male. — Length about 6.1 mm. Legs, 1423; first pair considerably the longest but not greatly thickened. Spines: first pair of tibiae with three pairs of moderately robust ventral spines not so crowded toward distal end as usual, promarginal series occupy almost exactly one half and retromarginal series only slightly more than one half of length of segment, also more nearly matched than usual; second pair of tibiae with irregular number of ventral spines, on left side only one promarginal terminal and on right side only one, the promarginal middle one; first two metatarsi with two pairs of ventral spines as usual. Distal outer corners of maxillae with small pointed extensions. Posterior row of eyes wider than anterior row in ratio of 7 : 6; eye space occupies almost four ninths of length of carapace, which is longer than wide in ratio of 89 : 71; posterior row of eyes occupies fourteen seventeenths of width of carapace at that level; PME nearer to ALE than to PLE in ratio of 2 : 3. Fang groove with

a single simple retromarginal tooth of moderate size, promargin with two teeth, the inner of which is small. Palp: patella somewhat longer than tibia, which has a short pointed apophysis only gently turned toward bulb; embolus relatively long, slender, and curved ventrally (Figs. 110–111). Color: all legs generally an amber color; all femora and patellae with black prolateral stripes; posterior two pairs of femora and patellae also with black retrolateral stripes; first pair of tibiae dark brown on distal half except on dorsal surface; second pair dark on both prolateral and retrolateral surfaces; last two pairs mostly dark everywhere but on dorsal surfaces; remaining segments mostly light at ends but dark in the middle; carapace a deep orange, with sparse short white hairs generally distributed, clustered somewhat around eyes, which are on black spots. Abdomen reddish dorsally, lighter at sides and ventrally; beginning about one third from base are two dark stripes, within which is a series of two or three pairs of small whitish spots.

Female. — Length about 9.0 mm. Legs, 4123; nearly equally stout with first slightly enlarged. Spines essentially like those of male, but with some variation. Outer distal corners of maxillae smooth. Eyes essentially like those of male. Color: all legs yellowish, with no dark markings; palps yellowish and hairy; all legs somewhat hairy; carapace yellow, with ocular area orange and eyes on black spots; a few long black hairs over whole dorsal surface, with tufts of a few black hairs each in regions of ALE, PME, and PLE. Abdomen with an almost uniformly pale yellowish ground color somewhat lighter laterally and beneath; two central dorsal narrow black stripes begin near the base and extend almost to anal tubercle; two small white spots usually show in posterior halves of the dorsal stripes. Epigynum: posterior marginal notch broad and shallow; near anterior border is a narrow scalloped margin, and behind the margin are two small depressions (Fig. 112).

Distribution. — Described from Kansas; also known from Oklahoma and Michigan. Collected twice in this state, both times in the southern part; Jackson and Hillsdale counties.

Phidippus purpuratus Keyserling

(Figures 113–116)

P. purpuratus Keyserling, 1884.
P. mystaceus Emerton, 1891.
P. borealis Banks, 1895.
P. galathea Peckham, 1901.
P. purpuratus Peckham and Peckham, 1909.

Male. — Length about 9.6 mm. Legs, 1423; first pair robust, much the stoutest but not much the longest; first pair strongly fringed with moderately long hair, others less heavily fringed. Spines: rather weak for legs so robust; first pair of tibiae with three pairs of ventral spines, those along promargin occupy distal half of segment, those along retromargin occupy about two thirds of segment; second pair of tibiae with one pair of terminal ventral spines and one other at about middle on retromargin. First two pairs of metatarsi with the usual two pairs of ventral spines. Distal outer corners of maxillae with very definite small hooks strongly cornified. Posterior end of sternum not so strongly convex as in many species. Posterior row of eyes wider than anterior row in ratio of 48 : 39; eye space occupies about three sevenths of length of carapace, which is longer than wide in ratio of about 7 : 6; posterior row of eyes occupies five sixths of width of carapace at that level; PME nearer to ALE than to PLE in ratio of 1 : 2. Fang groove with a single simple retromarginal tooth of moderate size and two promarginal teeth, the inner of which is very small (Fig. 115). Palp: patella somewhat longer than body of tibia, which has a single simple apophysis turned quite definitely toward the bulb; bulb terminates distally in a broad rugose area, on prolateral side of which the embolus emerges as a short stout spine (Figs. 113–114). Color: all legs and palps a rich dark reddish brown; fringes mostly black except on prolateral side of first patellae, where they are whitish; chelicerae iridescent-green in front and laterally; fang moderately robust and not strongly curved; some white scales on legs, especially the first pair; color of carapace similar to that of legs, with long black hair in tufts chiefly around ALE and PME, shorter black hair fairly uniformly distributed; ocular area darker with eyes on black spots. Abdomen generally lighter-colored; usually an indistinct light basal band, which extends laterally for about one third of distance to spinnerets, a little beyond its termination is a small isolated light oblique mark; centrally there are two faint dark

stripes, within which are usually four pairs of whitish spots; a fairly complete covering of whitish scales all over abdomen, but these are easily brushed off; laterally and ventrally color is darker; venter with a central dark stripe bounded by two narrow-beaded light stripes and containing near the middle two more incomplete narrow-beaded stripes.

Female. — Length about 11.0 mm. Legs, 4132. In general, like the male in all essential features of spines and fang groove. Outer distal corners of maxillae without hooks or extensions. Color: legs very similar to those of male except somewhat lighter; palps with much long white hair on last three segments, a tuft of black hair on prolateral side of tarsus and many white scales, especially on dorsal surface. Carapace colored as in male, but with more white scales. Abdomen dull brownish dorsally, with basal light band very narrow and often broken; centrally there are usually two darker stripes, with the four pairs of white spots clearer than in male; many white scales over dorsum and lateral sides; venter and lateral sides very similar to those of male. Epigynum: a fairly deep posterior marginal notch; at some distance anterior to the notch two rather deep and fairly large depressions, only partly separated by a suppressed and incomplete septum; the depressions connect anteriorly with a central depression, which has a very low narrow anterior margin (Fig. 116).

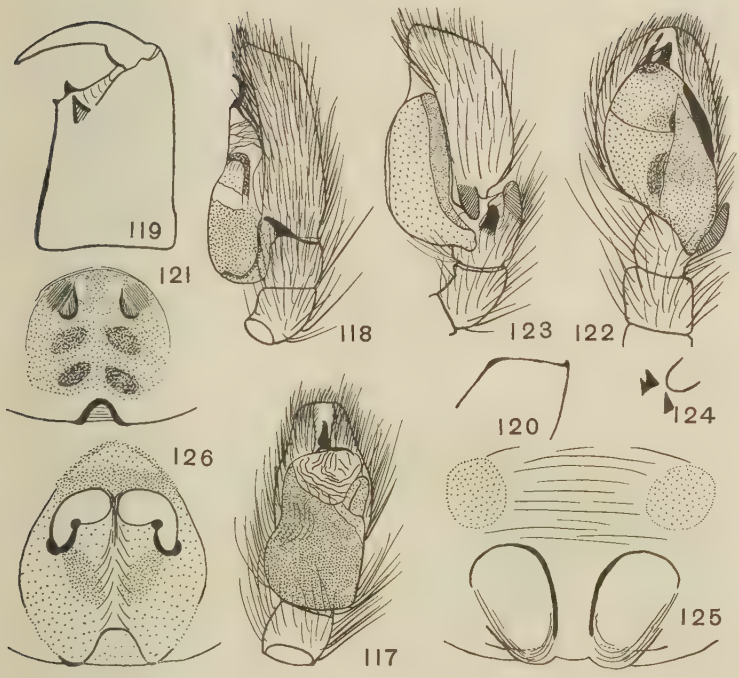
Distribution. — Well known from New England and New York; also known from several localities in the Midwest, and from Missouri, Utah, and Texas. Collected in Michigan at several localities in both peninsulas; fairly common.

Phidippus whitmanni Peckham

(Figures 117–121)

P. rufus Peckham, 1888.
P. whitmanni Peckham and Peckham, 1909.

Male. — Length about 6.9 mm. Legs, 1423; first pair only moderately longer and stouter than others; first pair well fringed (said to vary considerably among different individuals), others weakly fringed. Spines: first pair of tibiae with three pairs of ventral spines, those on promargin occupy slightly less than half of length of segment, whereas those on retromargin occupy almost exactly three fifths of length of segment. Second pair of tibiae with a pair of terminal ventral spines, right and left tibiae irregular with respect to others. First two pairs of metatarsi with two pairs of ventral spines



EXTERNAL ANATOMY OF SPIDERS

(Figures 117–126)

117. *Phidippus whitmanni*, male palpus, ventral view
118. *P. whitmanni*, male palpus, retrolateral view
119. *P. whitmanni*, left male chelicera
120. *P. whitmanni*, distal end of maxilla, male
121. *P. whitmanni*, epigynum
122. *Phlegra fasciata*, male palpus, ventral view
123. *P. fasciata*, male palpus, retrolateral view
124. *P. fasciata*, left male cheliceral teeth
125. *P. fasciata*, epigynum
126. *Phidippus insigniarius*, epigynum

as usual. Outer distal corners of maxillae with small hooklike extensions (Fig. 120). Posterior row of eyes longer than anterior row in ratio of about 6 : 5; eye space occupies almost half of length of carapace which is longer than wide in ratio of 49 : 41; posterior eyes occupy about thirteen sixteenths of width of carapace at that level.

Fang groove as usual, with a single retromarginal tooth and two promarginal teeth, the inner of which is small (Fig. 119). Palp: patella as usual, somewhat longer than body of tibia; tibial apophysis the usual spur of moderate size, broad basally, pointed distally, and distinctly turned toward bulb; anterior tarsal rugulose area triangular, with embolus a rather slender spine curved ventrally throughout its whole length (Figs. 117–118). Color: legs a reddish brown, with distal ends of femora and tibiae much darker; first leg with much white hair for fringes and quite well supplied with white scales; other legs much the same but less completely fringed; palps also with much long white hair and white scales, especially on dorsal side; chelicerae without much iridescence; carapace reddish generally, with many white scales, especially along lateral sides, ocular area darker. Abdomen generally reddish over dorsal area, with an obscure light basal band, which extends only a short distance on each side; there are faint dark central broken stripes; about midway there is a faint light oblique bar on each side and farther posterior another pair of smaller transverse bars; just above anal tubercle is a light area; venter generally reddish brown, with three central stripes, a median stripe and two others somewhat more lateral.

Female. — Length about 10.0 mm. Legs, 4123. Females have not been available during the writing of this description, but they are described by the Peckhams (1909) as very similar to the males in most respects. A light stripe extends from between AME to about opposite PLE. The black venter has two light stripes converging toward spinnerets. Epigynum: general shape oval, with a deep-bordered posterior marginal notch, an anterior obscure margin, behind which are small light areas (probably openings) and spermathecae (Fig. 121).

Distribution. — Well known from New England and New York; also reported from several localities in Ohio, Michigan, Illinois, and Wisconsin. Collected only once in Michigan, by R. R. Dreisbach; Lake County, June, 1940.

Genus PHLEGRA Simon, 1876

Carapace long, widest behind the middle, rather low and flat. Ocular space occupies only about one third of length of carapace. PME about midway between ALE and PLE. Metatarsi shorter than tarsi.

Phlegra fasciata (Hahn)

(Figures 122–125)

Salticus fasciatus Hahn, 1831.
P. fasciata Simon, 1901.
P. leoparda Peckham and Peckham, 1909.

Male. — Length about 6.0 mm. Legs, 4312; all pairs nearly equally stout. First pair of tibiae has three pairs of ventral spines, with all but the terminal spines on promargin moved far lateral in position and elongated; second pair of tibiae with considerable irregularity in my only mature male, on right side as described by the Peckhams (1909), with one pair of terminals and two others on retromargin, whereas on left side there are three pairs, as on first pair of tibiae; first two pairs of metatarsi with two pairs of long robust spines. Maxillae dilated distally but smooth over outer distal corners. Posterior row of eyes only slightly wider than anterior row; eye space occupies one third of length of carapace; posterior row of eyes occupies slightly more than four fifths of width of carapace at that level; PME just slightly closer to PLE than to ALE. Carapace longer than wide in ratio of 49 : 32; widest opposite interval between second and third coxae. Fang groove with a single simple rather slender retromarginal tooth and two slender closely crowded promarginal teeth (Fig. 124). Palp: patella and tibia about equal in length and both short; tibia with two retrolateral apophyses of moderate length, the smaller is contiguous to a strongly chitinized basal tarsal apophysis; tarsal bulb considerably swollen basally, at distal end of bulb is what is considered a slender embolus, and beside it a shorter stouter apophysis (Figs. 122–123). Color: all legs and palp generally dark brown, more or less streaked except tarsi, all of which are yellowish; carapace generally a rich dark-mahogany brown, two conspicuous white stripes extend from ALE nearly straight back to posterior margin; clypeus well covered with stiff bluish hairs; a narrow white border extends from clypeus on each side along margin for some distance; ocular area and lateral sides, often described as red, are simply lighter and a different shade of brown in my alcoholic specimens; sternum light brown. Abdomen with three white stripes, less conspicuous than those on carapace; elsewhere dark brown; a weakly developed dorsal shield. Venter dull brown, with four light obscure narrow-beaded stripes.

Female. — Length about 8.0 mm. Legs, 4312. Like the male in all essentials except as noted below. The reddish ocular area, reddish lateral areas of head, and bluish hair on clypeus all lacking; white stripes on carapace somewhat more extensive; usually a little spot of white between PME. Legs lighter brown and with dark annulations at distal and proximal ends of most segments. Epigynum posterior border scalloped; a short distance anterior two shallow depressions are partly encircled by well-defined margins; near anterior boundary two spermathecae lie more than twice the diameter of one of them apart (Fig. 125).

Distribution. - Quite well known from New England, New York, Ohio, and a few localities westward as far as the Rocky Mountains. Collected in Michigan only twice; both specimens are males; Calhoun and Mason counties.

Genus SALTICUS Latreille, 1884

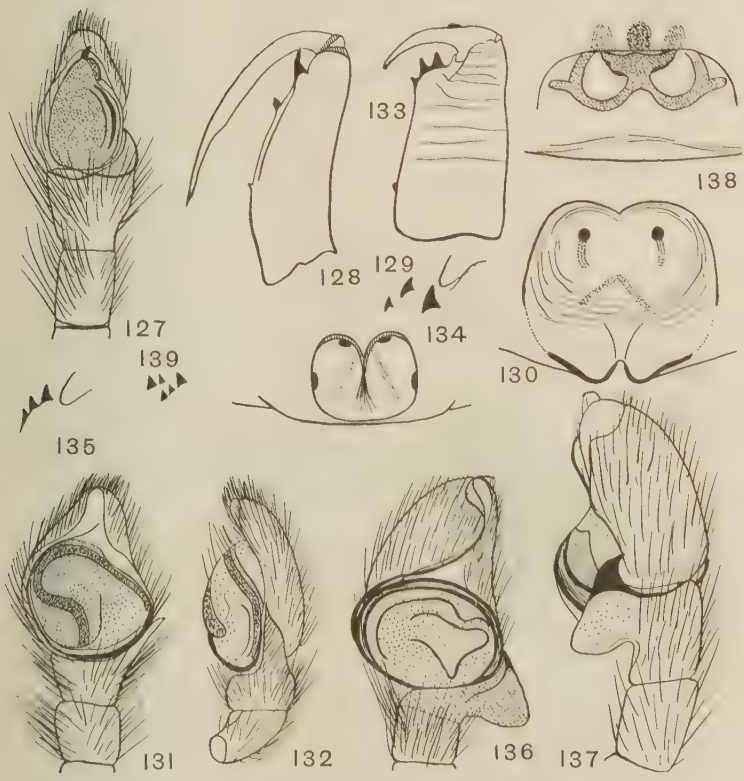
Carapace long, narrow in front, a little wider behind, moderately high and convex above; about two thirds as wide as long. Eye region occupies a little less than half of length of carapace; wider than long in ratio of about 11 : 9; PME either equidistant from ALE and PLE or a little nearer to PLE; width of posterior row considerably less than width of carapace at that level. Legs nearly equally stout. Sternum considerably narrowed in front. Lip a little longer than wide. Chelicerae considerably produced, porrect, and divergent in males; vertical and normal in females; only one simple retromarginal tooth near base of fang.

Salticus scenicus (Clerck)

(Figures 127–130)

Araneus scenicus Clerck, 1757.
Epiblemum faustum Hentz, 1832.
E. scenicum Emerton, 1891.
S. scenicus Simon, 1901.
S. scenicus Peckham and Peckham, 1909.

Male. — Length about 4.0 mm. Legs, 1423; first pair only slightly stouter than others. Ventral spines of first and second pairs of tibiae entirely lacking. Outer distal corners of maxillae not extended into hooks or tubercles. Eyes with usual generic features. Chelicerae strongly produced, porrect, with a long and somewhat sinuous fang; fang groove with a single large retromarginal tooth near base of fang



EXTERNAL ANATOMY OF SPIDERS

(Figures 127–139)

127. *Salticus scenicus*, male palpus, ventral view
128. *S. scenicus*, male chelicera
129. *S. scenicus*, left female cheliceral teeth
130. *S. scenicus*, epigynum
131. *Sitticus palustris*, male palpus, ventral view
132. *S. palustris*, male palpus, retrolateral view
133. *S. palustris*, left male chelicera
134. *S. palustris*, epigynum
135. *S. palustris*, left female cheliceral teeth
136. *Synemosyna formica*, male palpus, ventral view
137. *S. formica*, male palpus, retrolateral view
138. *S. formica*, epigynum
139. *S. formica*, left female cheliceral teeth

and two promarginal teeth, one of moderate size about one third from base of fang and a smaller one much farther removed (Fig. 128). Palp: patella somewhat longer than body of tibia; tibial apophysis a robust hook strongly excavated contiguous to base of tarsus; tarsal bulb moderately swollen, terminates in a short spinous embolus at distal end (Fig. 127). Color: all legs generally an amber color, with many dark annulations and streaks; palps amber, with many white scales, especially along dorsal surface and also with a moderate supply of long black hair; legs also with many white scales. Carapace generally dark brown, with ocular area black, sometimes with a lighter center showing two crescent-shaped black spots, but these are seen only when hair and scales have been rubbed off; usually a white central spot just above AME, a pair of dorsal white somewhat triangular spots just behind PLE; also a marginal white stripe all the way from white clypeus to posterior border; often a covering of iridescent light-colored scales over remainder of ocular area. Abdomen generally brownish, with a good deal of iridescence (said to be red in some individuals); a white basal band and two pairs of white oblique bars with more white near base of spinnerets.

Female. — Length 5.4 mm. Legs, 4132. Spines as described for the male. Chelicerae vertical and of normal size. Fang groove with a single stout tooth on retromargin and two promarginal teeth, the inner of which is smaller (Fig. 129). Color: lighter and less brilliant than in male, with less iridescence. Epigynum: relatively large; with a fairly deep posterior notch; a deep depression with scalloped anterior border (Fig. 130).

Distribution. — Reported from the greater part of North America, Europe, and North Africa. Fairly common all over the State of Michigan.

Genus SITTICUS Simon, 1901

Fang groove with no retromarginal teeth (in the only Michigan species), or with a single tooth in west coast species. Carapace fairly high and wide. Eye region considerably wider than long, anterior row about equal in width to posterior row; occupies slightly more than two fifths of length of carapace; PME slightly closer to ALE than to PLE; third row not quite so wide as carapace at that level. Anterior coxae widely separated; sternum oval and somewhat truncated anteriorly; labium as wide as long.

Sitticus palustris (Peckham)

(Figures 131–135)

Attus palustris Peckham, 1883.
S. palustris Simon, 1901.
A. sylvestris Emerton, 1891.
S. palustris Peckham and Peckham, 1909.

Male. — Length about 3.9 mm. Legs, 1423; first pair only a little stouter than others and with no appreciable fringes. Spines: first pair of tibiae with three pairs of ventral spines (the Peckhams record only two pairs, but I have failed to find any of my specimens which have less than one ventral terminal and two other pairs of matched spines, some have three pairs, and I consider this condition to be normal); second pair of tibiae with much irregularity, the most frequent condition being two ventral retromarginals, either with or without a terminal one on promargin; first two pairs of metatarsi with two pairs of ventral spines. Outer distal corners of maxillae without hooks or tubercles. Posterior row of eyes only slightly wider than anterior row; eye region occupies nearly four ninths of length of carapace, which is longer than wide in ratio of 17 : 13; posterior row of eyes occupies nearly fourteen fifteenths of width of carapace at that level; PME nearer to ALE than to PLE in ratio of 5 : 6. Chelicerae normal; fang groove with no retromarginal teeth and with three promarginal teeth closely crowded together (Fig. 133). Palp: patella a little longer than body of tibia; tibial retrolateral apophysis a stout spur, pointed distally and longer than body of tibia; bulb wider than long, containing a long looped tubule; embolus arises near base on retrolateral side and curves around more than two thirds of circumference of bulb (Figs. 131–132). Color: legs and palps generally a light brown, with many dark spots and streaks, also with many white scales dorsally and prolaterally, especially near the joints; palpal femur snow white, also white fringes on patella and tibia; carapace dark brown with scaly iridescence in ocular area, a white margin on clypeus continues on each side to posterior border; a broken white central narrow stripe from posterior declivity to opposite PME; another broken white stripe on each side from near posterior margin to PME and this extends beyond to surround anterior eyes, where there are some reddish hairs. Abdomen: a dull brownish, with a light basal band which extends laterally as a narrow stripe sometimes almost to the anal tubercle; also white spots

at end of first quarter, two larger transverse elongated spots making almost a bar across the middle; venter with a covering of dirty white hairs.

Female. — Length, 5.44 mm. Legs, 4123. Spines: show considerable irregularity; apparently one terminal ventral on promargin on first tibia and two other pairs, but those on promargin are moved over so far laterally as to appear almost as much lateral as ventral; second tibiae appear usually to have a single terminal ventral spine on promargin and two others on retromargin. First two pairs of metatarsi have the usual two pairs of ventral spines on each segment. Fang groove with teeth as shown in Figure 135. Color: essentially like that of male but with less striking contrasts. Other general features essentially like those of male. Epigynum: no notch in posterior margin; a single large depression with, perhaps, a suppressed septum in the center (Fig. 134).

Distribution. — Well known from New England, New York, New Jersey, Ohio, Illinois, and Michigan. Collected quite frequently in numerous localities in both peninsulas.

Genus SYNEMOSYNA Hentz, 1845

Most antlike of our Michigan Salticidae. Carapace long and slender; with a deep transverse groove nearly in middle; with posterior end narrowed to a tubular form, thus apparently adding to length of abdomen. Eye space occupies about one third of length of carapace. PME a little closer to ALE than to PLE. Anterior row of eyes strongly recurved. Abdomen also with a dorsal groove (deep in males) just in front of middle.

Synemosyna formica Hentz

(Figures 136–139)

Janus gibberosus C. L. Koch, 1846.
S. formica Emerton, 1891.
S. formica Simon, 1901.
S. formica Peckham and Peckham, 1909.

During the writing of this description I had for study both males and females from Massachusetts and Indiana; they belong to the Museum of Comparative Zoölogy at Harvard College.

Male. — Length, 4.48 mm. Legs, 4312; nearly equally stout. Spines weak and somewhat difficult to see. Chelicerae (see fig. 743,

p. 673, Gertsch-Comstock, 1940) somewhat developed, divergent, and medially somewhat excavated; fang groove with several small teeth on promargin, and a small tooth together with a larger compound tooth on retromargin. Posterior row of eyes wider than anterior row in ratio of 38 : 35; eye space wider than long in ratio of 19 : 17; occupies just a little more than one third of length of carapace, which is longer than wide in ratio of 47 : 19; PME nearer to ALE than to PLE in ratio of 6 : 9; posterior row occupies more than nine tenths of width of carapace at that level; anterior row of eyes strongly recurved; AME close together; diameter of AME greater than that of ALE in ratio of 7 : 3; diameter of PLE greater than that of PME in ratio of 6.5 : 2. Cephalic part of carapace rather high, gently arched to just behind PLE, then carapace dips steeply into deep median transverse groove; beyond groove carapace rises to a height about three quarters as great as elevation of head; then carapace descends again to cylindrical posterior end. Pedicel with a large strongly chitinized dorsal plate and a smaller ventral plate. Abdomen longer than wide in ratio of almost 3 : 1; just beyond first third there is a deep transverse groove, and behind this the posterior half is somewhat bulbous; a well-developed dorsal shield and a strongly chitinized ventral plate in front of the genital furrow extend dorsally to meet the dorsal shield. Palp: patella about as long as tibia, which has a very stout retrolateral apophysis, which is greatly extended ventrally and strongly chitinized anteriorly, where it terminates in a sharp point; the bulb is strongly swollen; the embolus is a long slender filament coiled about the bulb and then extended distally in a long loop (Figs. 136–137). Color: all legs an amber color, progressively darker toward the last pair; first legs with a conspicuous prolateral black stripe on patellae, tibiae, and metatarsi; a less conspicuous brown retrolateral stripe on tibiae and metatarsi; body generally a rich mahogany brown (black on several of my immature specimens); all eyes except AME on black spots, ocular area elsewhere lighter; often a light spot in middle of the transverse groove and another at each end of the groove near the margin. Abdomen usually has a light band across the bottom of the transverse groove continued onto the broad light area on venter.

Female. — Length about 5.7 mm. Essentially like the male except for minor features. Fang groove with teeth as shown in Figure 139. Somewhat lighter-colored than male, and the light spots are much

more conspicuous. Dorsal shield reduced to a small cap. Epigynum: a simple area much wider than long, with a series of tubules making an intricate pattern (Fig. 138).

Distribution. — Believed to occur throughout the entire United States and southeastern Canada. Collected in Michigan several times, but only in Calhoun and Midland counties.

Genus TUTELINA Simon, 1901

The generic status of the species included here is uncertain, but there is no space in this paper for the discussion of the problem. There are objections to every suggestion thus far made regarding the taxonomic treatment of these species. Tentatively the following features may be considered common and sufficient to establish the genus: carapace of moderate height or lower and flatter (*hartii*); abdomen of moderate length and cylindrical. Legs 1423 in male; 4123 in females. Posterior row of eyes somewhat wider than anterior row; eye space occupies less than one half of carapace; PME closer to ALE than to PLE. Fang groove with an elongated keel-like ridge on promargin and a simple small tooth on retromargin. More or less iridescence on both abdomen and carapace. Male palps built in accord with pattern exhibited by the male of *T. elegans* (Figs. 140–141); epigyna constructed in accord with pattern exhibited by the females of *T. elegans* (Fig. 143).

KEY TO THE SPECIES OF *TUTELINA*

MALES

1. First tibia with a tuft of hair on ventral surface near distal end; embolus a moderately stout spine enlarged near distal end and springing from a bulbous base; tibial apophysis a small pointed spur (Fig. 140) *T. elegans*, p. 211
1. Not with combination of features given above 2

2. Most antlike of the Michigan species; carapace more rounded than usual; tibial retrolateral apophysis a stout spur narrowed and then turned ventrally near distal end; embolus a fairly stout pointed spur (Fig. 144) *T. formicarius*, p. 213
2. Not with combination of features given above 3

3. A short stiff ventral fringe on anterior tibiae extending onto distal end of patella; carapace unusually low and flat; abdomen with a lighter (often reddish) margin nearly encircling dorsum; embolus a stout spine not at all spatulate distally ..... *T. hartii*, p. 214

3. Resembles *T. elegans;* tibial apophysis short, broad at base, distally pointed; embolus a blunt stout spine, constricted a little in middle, somewhat spatulate distally ..... *T. similis*, p. 216

FEMALES

1. Epigynum with a very deep narrow posterior marginal notch and two nearly parallel short black spots on each side near the middle (Fig. 146); no basal abdominal band; legs conspicuously striped *T. formicarius*, p. 213
1. Not with combination of features given above 2

2. Epigynum with a broad, moderately deep posterior marginal notch and a single elongated procurved black spot on each side somewhat in front of middle (Fig. 150); abdomen dorsally dark but marginally lighter (often reddish), with a broad encircling band; legs not conspicuously striped *T. hartii*, p. 214
2. Not with combination of features given above 3

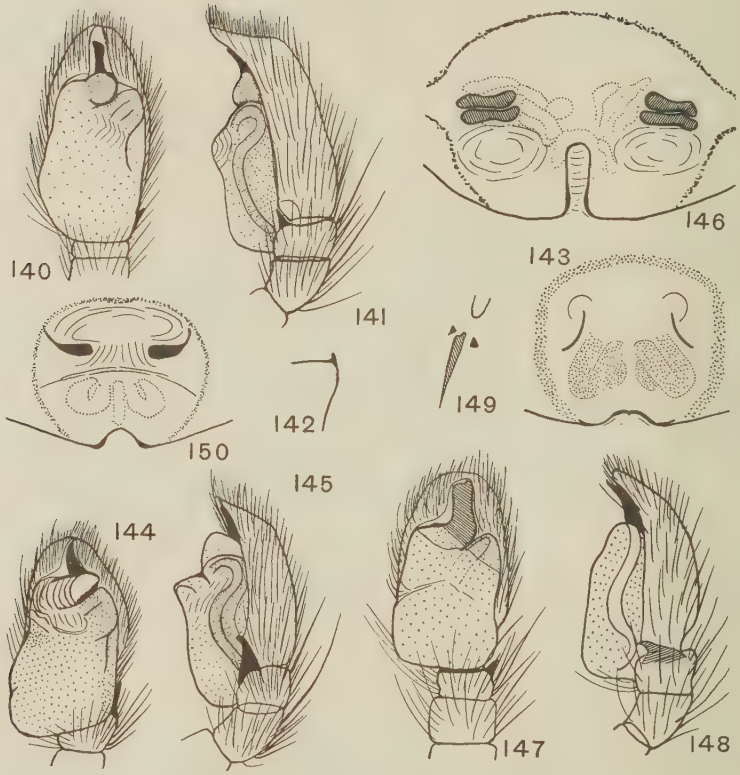
3. Epigynum with a broad and shallow posterior marginal notch; openings to spermathecae more or less oblique (Fig. 154); anterior tibiae with not more than two pairs of ventral spines ..... *T. similis*, p. 216
3. Epigynum with a broad and shallow posterior marginal notch slightly scalloped; openings to spermathecae with recurved anterior boundaries (Fig. 143); anterior tibiae ordinarily with three pairs of ventral spines *T. elegans*, p. 211

Tutelina elegans (Hentz)

(Figures 140–143)

Attus elegans Hentz, 1845.
A. superciliosus Hentz, 1845.
Icius elegans Keyserling, 1884.
T. elegans Peckham and Peckham, 1909.

Male. — Length, 4.0 mm. Legs, 1423; first pair much the longest and somewhat the stoutest, but all slender; first pair weakly fringed, but with a conspicuous ventral distal tuft of black hair on first tibiae. Spines: first pair of tibiae with three pairs of ventral spines; second pair of tibiae irregular, but usually with a pair of terminal ventral spines and two others along retromargin; first two pairs of metatarsi with two pairs of ventral spines. Outer distal corners of maxillae extended into small hooks (Fig. 142). Posterior row of eyes a little wider than anterior row; eye space occupies about four ninths of length of carapace, which is longer than wide in ratio of about 3 : 2; posterior row of eyes occupies five sixths of width of carapace at that level. Fang groove with a single rather small retromarginal tooth; promargin with no true teeth, but with an elongated ridge strongly chitinized and with a row of short black stiff bristles.



EXTERNAL ANATOMY OF SPIDERS

(Figures 140–150)

140. *Tutelina elegans*, male palpus, ventral view
141. *T. elegans*, male palpus, retrolateral view
142. *T. elegans*, distal end of left male maxilla
143. *T. elegans*, epigynum
144. *Tutelina formicarius*, male palpus, ventral view
145. *T. formicarius*, male palpus, retrolateral view
146. *T. formicarius*, epigynum
147. *Tutelina hartii*, male palpus, ventral view
148. *T. hartii*, male palpus, retrolateral view
149. *T. hartii*, left male cheliceral teeth
150. *T. hartii*, epigynum

Palp: both tibia and patella short, the latter somewhat the longer; tibial apophysis a short, sharply pointed spur; a short but fairly stout embolus arises from bulbous base (Figs. 140–141). Color: legs generally yellowish; dorsal black stripes along most segments. several segments also with prolateral and retrolateral black stripes. Greenish-yellow iridescent scales generally over abdomen and carapace. Most of ocular area black; ocular tufts black, with few white scales; posterior declivity dark brownish, with remainder of carapace a golden yellow overlaid with white scales sparsely distributed; a narrow white marginal stripe. Abdomen generally a dark brown, only a little lighter ventrally.

Female. — Length about 4.5 mm. Legs, 4123. Spines: first and second tibiae may have no spines, but they appear usually to have one or two, none terminal. Outer distal corners of maxillae smooth, without hooks. Other features essentially like those in male. Color: legs and carapace like those in male; abdomen sometimes with a light basal band; otherwise dark like the male, but more iridescence is present. Epigynum: rather inconspicuous and easily confused with others, especially when immature; a fairly broad-bordered notch in middle or posterior margin; a fairly well-defined recurved anterior border; two small openings about twice the long diameter of one of them apart (Fig. 143).

Distribution. — Well known from New England, New York, the eastern coastal states, several southern states, the Midwest as far westward as Nebraska and Oklahoma. Collected in Michigan from several localities in Emmet, Midland, Oceana, and Calhoun counties.

Tutelina formicarius (Emerton)

(Figures 144–146)

Icius formicarius Emerton, 1891.
I. formicarius Banks, 1895.
I. formicarius Peckham and Peckham, 1909.

Male. — Length, 5.0 mm. Legs, 1423; first pair only a little more robust than others; without definite fringes. Spines: first pair of tibiae with three pairs of weak ventral spines; second pair of tibiae with a pair of terminal ventral spines, two more along retromargin and only one more along promargin; first two pairs of metatarsi with two pairs of weak ventral spines. Outer distal corners of maxillae with robust hooks. Carapace fairly robust and rounded

above. Posterior row of eyes wider than anterior row in ratio of 12 : 11; ocular space occupies about three sevenths of length of carapace, which is longer than wide in ratio of 35 : 23; posterior row of eyes occupies about six sevenths of width of carapace at that level; PME closer to ALE than to PLE in ratio of 13 : 18. Fang groove with a long chitinized keel-like ridge on promargin and a single simple tooth on retromargin. Palp: patella somewhat longer than short body of tibia; tibial retrolateral apophysis a stout spur, which extends parallel to tibia and near tip turns ventrally; embolus a short curved pointed spur (Figs. 144–145). Color: generally a dark brown; all legs broadly striped but less conspicuously than in *T. elegans;* many white scales on palps and legs, especially the first pair; a white marginal stripe on carapace; a poorly developed dorsal abdominal shield. Some iridescence, especially on abdomen; venter dark except the area in front of the genital furrow, which is much lighter.

Female. — Length about 5.7 mm. Legs, 4123. Essentially like the male except in minor features. Color is more brilliant, at least in those specimens which I have examined. Epigynum: most distinctive in all Michigan species; the posterior marginal notch is very long and narrow; near the middle on each side are two short dark parallel bands (Fig. 146).

Distribution. — Well known from southern New England and New York; also known from Ohio and Michigan. Collected only twice in Michigan, once in Leelanau County and once in Cheboygan County.

Tutelina hartii (Emerton)

(Figures 147–150)

Icius hartii Emerton, 1891.
I. hartii Peckham and Peckham, 1909.

Male. — Length, 4.2 mm. Legs, 1423; first pair considerably the stoutest, especially the femora, which are also flattened laterally, and patellae and tibiae; first pair with fringes, weak on femora but heavy on patellae and tibiae. Spines: first tibiae with three pairs of ventral spines, those on promargin crowded onto distal half, those on retromargin occupying more than distal half; ventral spines on second pair of tibiae same as first, except that the most proximal on promargin are lacking; first two pairs of metatarsi with two pairs of ventral

spines each. Whole outer edge of maxillae strongly chitinized and outer distal corners drawn out into short tubercles. Posterior row of eyes only slightly wider than anterior row; ocular space occupies about four ninths of length of carapace; posterior row occupies about five sixths of width of carapace at that level; PME closer to ALE than to PLE in ratio of 5 : 6. Fang groove with a single simple small retromarginal tooth; promargin with a small tooth and a chitinized elongated ridge (Fig. 149). Palp: patella somewhat longer than tibia when viewed dorsally; tibial apophysis a short pointed spur directed ventrally toward bulb; tarsus somewhat swollen basally; bulb almost equally quadrilateral; embolus a stout spine, blunt and slightly notched distally (Figs. 147–148); scantily fringed with long white hair. Color: all legs light brownish, darkened prolaterally and retrolaterally but not definitely striped; a scant covering of white scales; fringe on first pair dark brown. Carapace a medium brown, with dorsal surface lighter except ocular area, which is darker; a narrow white marginal stripe; white scales dorsal to first row of eyes. Dorsum generally a reddish color, with a darker figure within the reddish area; lateral sides and venter almost black; some iridescence shows on both carapace and abdomen. Whole carapace lower and flatter than usual in the genus.

Female. — Length about 4.2 mm. Legs, 4123; first leg essentially like that of male, but the fringe less well developed. Ventral spines of first two pairs of tibiae and metatarsi like those of male, except that on first tibiae they are not crowded toward distal half and the terminal spines on ventral side of second metatarsi are lacking. Outer edges of maxillae strongly chitinized, but not provided with tubercles at outer distal corners like those of male. Color: very similar to that of male; there is more iridescence, especially on abdomen, where there is a pinkish white basal band that extends dorsolaterally somewhat brokenly to posterior end. Epigynum: a broad, moderately deep posterior marginal notch; a little distance in front of middle on each side is a single dark procurved spot (Fig. 150).

Distribution. — Well known in New England and New York; also reported from Ohio, Michigan, Illinois, Wisconsin, and Nebraska. Probably collected in Michigan only four times, always in the vicinity of Albion, Calhoun County, but two females are doubtfully assigned to the species.

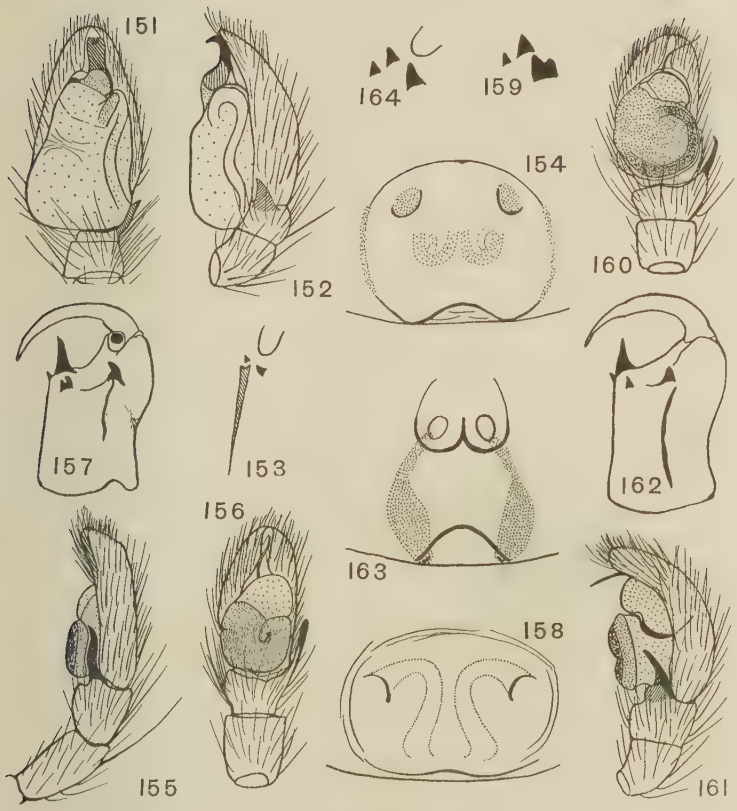
Tutelina similis (Banks)

(Figures 151–154)

Icius similis Banks, 1895.
I. similis Peckham and Peckham, 1909.

Male. — Length about 4.0 mm. Legs, 1423; first legs only slightly enlarged and scantily fringed except patella and tibia, where long white hair is well developed (the Peckhams state that males usually have black fringes). Spines: first pair of tibiae usually with two pairs of ventral spines, most proximal pair lacking; second pair of tibiae with only two ventral spines, both retromarginal; first pair of metatarsi with usual two pairs of ventral spines, but second pair of metatarsi apparently has only one pair (terminal); all spines slender, fragile, difficult to see. Outer distal corners of maxillae drawn out into blunt hooks. Posterior row of eyes only slightly wider than anterior row; eye space occupies nearly eight seventeenths of length of carapace, which is longer than wide in ratio of 84 : 55; posterior row of eyes occupies twelve thirteenths of width of carapace at that level; AME closer to ALE than to PLE in ratio of 5 : 6. Fang groove with a small retromarginal tooth and a small promarginal tooth followed by a long low strongly chitinized ridge or keel (Fig. 153). Palp: patella about twice as long as body of tibia, which has a short basally stout distally pointed apophysis, which is directed diagonally toward the distal end of the tarsus; tarsal bulb swollen basally (Figs. 151–152); embolus a stout spine slightly narrowed in the middle, curved ventrally, somewhat spatulate apically (I do not see the distal end as it was illustrated by J. H. Emerton in the Peckhams' [1909] figures). Color: all legs yellowish, with narrow black stripes less distinct than in *T. elegans;* carapace generally reddish brown, with numerous white scales and a few white hairs; ocular area almost black; just above AME are two incurved tufts of brown hairs mixed with a few white scales and hairs; dorsum of abdomen a darker brown with a few white scales, a few light hairs and many glistening iridescent scales; venter is lighter, with many of the glistening scales.

Female. — Length about 4.8 mm. Legs, 4123. Spines: apparently only a distal terminal pair of ventral spines on first pair of tibiae; second pair of tibiae with none on ventral surface; first pair of metatarsi with two pairs of ventral spines; second pair with one pair of ventral spines (terminal). No hooks or tubercles on outer distal



EXTERNAL ANATOMY OF SPIDERS (Figs. 151–164)

151. *Tutelina similis*, male palpus, ventral view
152. *T. similis*, male palpus, retrolateral view
153. *T. similis*, left male cheliceral teeth
154. *T. similis*, epigynum
155. *Zygoballus bettini*, male palpus, retrolateral view
156. *Z. bettini*, male palpus, ventral view
157. *Z. bettini*, left male chelicera
158. *Z. bettini*, epigynum
159. *Z. bettini*, left female cheliceral teeth
160. *Zygoballus nervosus*, male palpus, ventral view
161. *Z. nervosus*, male palpus, retrolateral view
162. *Z. nervosus*, left male chelicera
163. *Z. nervosus*, epigynum
164. *Z. nervosus*, left female cheliceral teeth

corners of maxillae. Color as described for the male, except that legs are more distinctly striped; carapace darker; no hair tufts above AME; abdomen with a faint light basal band, at least in some individuals, darker with fewer iridescent scales. Epigynum: a distinct posterior marginal notch; small openings somewhat oblique in position (Fig. 154).

Distribution. — Known from New England, New York, Michigan, Wisconsin, Illinois, Nebraska, Washington State, New Mexico, Arizona, and British Columbia. Collected in Michigan from several localities in the Lower Peninsula. Females are easily confused with those of *T. elegans*, and they have sometimes been referred to the wrong species.

Genus ZYGOBALLUS Peckham, 1885

Carapace high, a little longer than wide, widest at level of PLE, steeply declivitous behind these eyes. Ocular region about one fifth wider than long, posterior row of eyes somewhat wider than anterior row, ocular region occupies about three fifths of length of carapace. PME nearer to ALE than to PLE; latter row as wide as carapace at that level.

KEY TO THE SPECIES OF *ZYGOBALLUS*

MALES

1. First coxae at least five times as long as wide; anterior face of chelicerae with a stout tooth near base of fang; fang groove with a stout retromarginal, usually hammerheaded, tooth ..... *Z. bettini*, p. 218
1. First coxae much less than five times as long as wide; anterior face of chelicerae without stout tooth near base of fang (sometimes a small tooth); fang groove with a stout retromarginal tooth, which is usually not at all hammerheaded ..... *Z. nervosus*, p. 220

FEMALES

1. Epigynum with a broad, deep posterior marginal notch; with a single large median opening far from posterior margin and within the large opening two small openings to spermathecae ..... *Z. nervosus*, p. 220
1. Epigynum with a very shallow posterior marginal notch; with no large median opening but with the two small openings far apart and directed obliquely ..... *Z. bettini*, p. 218

Zygoballus bettini Peckham

(Figures 155–159)

Male. — Length about 4.0 mm. Legs, 1423; first pair much elongated, including coxae and trochanters, with femora consider-

ably thickened. Spines: first pair of tibiae with three pairs of ventral spines, none terminal and not well matched; those on promargin more robust and closer together than those on retromargin; second pair of tibiae with three single unmatched ventral spines along retromargin; first two pairs of metatarsi with two pairs of ventral spines each. Outer distal corners of maxillae without hooks or tubercles, but with whole outer surface somewhat excavated. Positions of eyes generic. Chelicerae strongly developed, somewhat porrect, strongly divergent; with a prominent tooth on anterior face near base of fang, which is quite sinuous; fang groove with a small bifid tooth and a large somewhat hammerheaded excavated tooth on retromargin; also a large elongated promarginal tooth, at base of which is a small one (Fig. 157). Palp: patella somewhat longer than body of tibia; tibial retrolateral apophysis a slender spur reaching to transverse division of tarsus; tarsus divided into a lighter anterior smaller part and a darker reddish-brown posterior part; embolus a slender elongated spine (Figs. 155–156). Color: first pair of legs, chelicerae, and palps all a rich reddish brown, all other legs yellowish, with a few reddish-brown spots and regions, especially on fourth legs. Carapace a rich reddish brown overlaid with white scales; eyes located on black spots; clypeus with many white scales, which extend over anterior face of chelicerae. Abdomen a lighter reddish brown dorsally, with a light basal band which extends laterally for a short distance on each side; also two pairs of somewhat oblique light bars farther posterior and fine light lines over posterior half.

Female. — Length about 4.5 mm. Legs, 4123; first pair somewhat enlarged as in male, but coxae and trochanters not much elongated. Ventral spines of first two pairs of tibiae and metatarsi as recorded for the male, except that second tibiae have only two on retromargin. Chelicerae normal; fang groove with two simple promarginal teeth and a stout bifid retromarginal tooth (Fig. 159). Color: first pair of legs with only femora a rich reddish brown, other segments of first legs and all other legs and palps also yellowish, with a few reddish-brown spots, mostly at distal ends of segments of legs. Carapace essentially like that of males. Abdomen lighter-colored, with more light spots dorsally; in addition to light basal band there is a series of paired central light spots and dark spots alternating from base to near anal tubercle, but these are variable in extent and number in different individuals. Epigynum: somewhat wider than long; very simple,

with a shallow posterior marginal notch and two small openings far apart and oblique in position (Fig. 158).

Distribution. — Well known from New England southward to Florida and westward to Nebraska and Texas. Collected in several localities in the southern part of the Southern Peninsula of Michigan; sometimes found in large numbers in a small area, as they were near Homer, Calhoun County, June, 1935.

Zygoballus nervosus (Peckham)

(Figures 160–164)

Eris nervosus Peckham, 1891.
Z. terrestris Emerton, 1891.
Z. nervosus Peckham and Peckham, 1909.

Male. — Length about 3.5 mm. Legs, 1423; first pair somewhat enlarged, especially the femora. Spines: first pair of tibiae with three pairs of ventral spines; second pair of tibiae with only two ventral spines, both retromarginal; first two pairs of metatarsi with two pairs of ventral spines each. Distal outer corners of maxillae without hooks or tubercles; outer surfaces only mildly excavated. Positions of eyes generic. Chelicerae strongly developed, porrect, divergent, deeply excavated along fang groove; either with or without a small tooth on front face near base of fang; fang groove with a large retromarginal tooth not hammerheaded, as in the male of *Z. bettini*, and a small simple retromarginal tooth near inner end of groove; also a single stout promarginal tooth with a small one at its base (Fig. 162). Palp: segments generally more robust than in *Z. bettini;* patella somewhat longer than body of tibia, but both segments about as wide as long; tibial apophysis a slender spur, but does not extend more than halfway to transverse division of bulb; embolus a slender considerably elongated filament (Figs. 160–161). Color: all legs generally a light amber, first pair of femora a reddish brown and other femora darkened a little prolaterally and retrolaterally. Palps and chelicerae a reddish brown. Carapace reddish brown, with eyes on black spots, with numerous white scales; clypeus covered with white scales; considerable iridescence in ocular area. Abdomen a rich reddish brown dorsally, with several faint light chevrons in posterior half; a light basal band, which continues laterally for more than half of distance to spinnerets.

Female. — Length about 4.2 mm. Legs, 4123; first pair enlarged

as in male. Ventral spines of first two pairs of tibiae and metatarsi essentially like those in male. Chelicerae normal; fang groove with two simple promarginal teeth and a single simple retromarginal tooth (Fig. 164). Color: legs much as in male, but with many reddish-brown spots and darkened areas. Carapace very similar to that of male. Abdomen lighter than in male; in some individuals whole dorsum a mottled reddish brown and light yellow; in others a light basal band followed by a series of oblique light bars with two large light spots behind them; still farther back there are often several indistinct chevrons. Epigynum: much longer than wide; a broad and fairly deep posterior marginal notch; a single obscure central opening with two smaller openings within (in well-developed and cleaned individuals [Fig. 163]).

Distribution. — Well known from New England and New York, southward as far as Virginia and westward as far as Illinois. Fairly common in the Southern Peninsula of Michigan, where it has been taken in several localities.

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NOTES ON NAIADES FROM THE GREEN, SALT, AND TRADEWATER RIVERS IN KENTUCKY

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SHORTLY before his death in 1927 Dr. A. E. Ortmann published a paper on the mussels of the Green River drainage in Kentucky. On the basis of the factual information set forth in his report (1926 : 186) he was able to stress particularly that "there is a sharp line between Cumberland and Green Rivers in southern Kentucky, separating two apparently old faunas, the Ohioan and the Cumberlandian." Additional information presented here indicates that this observation is correct.

In 1927, the year following Ortmann's publication, Mr. William J. Clench and Dr. Peter Okkelberg visited the Green River, collecting for the Museum of Zoology, University of Michigan. A special effort was made to obtain specimens from the lower portion of that drainage, a region hitherto unexplored and one obviously in need of examination (see map, Plate VIII in Ortmann's 1926 paper). Also, sufficient collections were made in the Tradewater and Salt rivers to establish the fact that an Ohioan fauna was present in these important tributaries to the Ohio. Ortmann was well aware of the urgency of further investigation in the Salt River when he wrote: "There is yet in Kentucky the Salt River system, between the Green and Kentucky Rivers. . . . However, it is to be expected, that this drainage also has a fauna similar to those of the Kentucky and Green Rivers, that is to say, an Ohioan fauna, without typical Cumberlandian elements."

TABLE I

MUSSEL DISTRIBUTION OF THE GREEN RIVER DRAINAGE OF KENTUCKY, TOGETHER WITH THOSE OF THE TRADEWATER AND SALT RIVERS

| | | |

| | | |

With the data now available we need no longer merely suppose that the Salt River contains a mussel assemblage similar to that of the Green River. Furthermore, the collection made in the Tradewater clearly shows the absence of Cumberlandian species in that drainage system.

In order to simplify and clarify the presentation of the pertinent factual data contributed by the collections of Clench and Okkelberg, a distribution chart has been prepared (Table I). The species list is similar to that given by Ortmann for the Green River. The column headings are so arranged that collections of species (indicated by +) in the tributaries and the upper reaches of the river are noted first. All the records are new and serve to supplement those given by Ortmann in his Green River report.[1]

An examination of the chart shows some interesting conditions when the species are considered in the light of information recorded by Ortmann. Several listed by him were not found by Clench and Okkelberg. Chief among these are: *Fusconaia ebenus, Plethobasus cyphyus, Anodontoides ferussacianus, Carunculina parva, Micromya fabalis, Ligumia subrostrata, Truncilla donaciformis,* and *Dysnomia flexuosa.* It is important in this connection to note that all but the last of these were given by Ortmann on the strength of the list presented by S. F. Price (1900). Although all eight species are Ohioan and likely to occur in the Green River, we must state that they have not been discovered. Several others not taken by Clench and Okkelberg are known to be in the Green River, but are collected only rarely. They are: *Quadrula metanevra, Anodonta imbecillis* (taken in Salt River), *Lastena lata, Anodonta suborbiculata, Obovaria retusa,* and *Dysnomia torulosa.* For some curious reason Ortmann failed to list *Lasmigona complanata* as a possibility in the Green River. Perhaps the fact that so few collections were available to him from the lower portion of that drainage accounts for this omission. The chart clearly shows that *L. complanata* is confined to the lower Green. Another addition to the list presented by Ortmann is *Dysnomia sulcata.* He states (1926 : 185): "All these representatives have been found in Green River, with the exception of *Dysnomia sulcata.*" Al-

[1] The following species of Ortmann's list are not represented in the table: (1) *Fusconaia ebenus,* (11) *Quadrula metanevra,* (23) *Lastena lata,* (29) *Anodontoides ferussacianus,* (36) *Obovaria retusa,* (42) *Carunculina parva,* (44) *Micromya fabalis,* (48) *Ligumia subrostrata,* (59) *Dysnomia torulosa,* (60) *D. flexuosa = foliata.*

though he was forced to assume the absence of *D. sulcata* in this river, later collections now reveal its presence.

Unless one is familiar with the animals under discussion, it will be difficult to appreciate just what species are regarded as typifying a "Cumberlandian" naiad fauna. Even among conchologists this matter is not altogether clear because the exact ranges of certain mussels must be determined before it can be ascertained to which major faunal assemblage a doubtful species belongs. However, Ortmann (1924 : 42–44) has suggested a list of species to be considered Cumberlandian. The names are given here so that one may see by comparison the striking contrast between this compilation of Cumberlandian elements and those in the distribution chart that contains a purely Ohioan or Interior Basin fauna. The following list comprises the species that are unquestionably restricted to the upper Cumberland River:

Fusconaia barnesiana
Quadrula intermedia
Pleurobema oviforme
Alasmidonta minor
Ptychobranchus subtentum
Actinonaias pectorosa
Carunculina moesta
Medionidus conradicus
Pegias fabula
Dromus dromas
Micromya nebulosa
Micromya vanuxemensis
Micromya taeniata
Micromya trabalis
Dysnomia brevidens
Dysnomia lenior
Dysnomia turgidula
Dysnomia florentina
Dysnomia capsaeformis
Dysnomia arcaeformis
Dysnomia haysiana
Dysnomia lewisi

Three additional Cumberlandian species are in the upper Tennessee River drainage, but are absent from the Cumberland River:

Lexingtonia dolabelloides
Lasmigona holstonia
Conradilla caelata

The naiad fauna of the Salt and Tradewater rivers is clearly Ohioan, as is shown by the chart. The addition of the Tradewater River to the list of rivers lacking a trace of Cumberlandian elements is of particular interest since it reveals that the line separating these two distinct faunal assemblages, the Ohioan and the Cumberlandian, is evidently just as sharp as Ortmann anticipated. It would be interesting to have an explanation of the presence of such clearly defined distribution patterns from those who maintain that passive agents other than fishes are responsible for the distribution of the mussels now found in those rivers.

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THE AMPHIBIANS AND REPTILES OF THE UNIVERSITY OF MICHIGAN BIOLOGICAL STATION AREA IN NORTHERN MICHIGAN

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INTRODUCTION

IN 1908 the University of Michigan established the Biological Station at Douglas Lake, Cheboygan County, Michigan. Since then a great deal of work has been done on the vertebrate fauna of the region, and it is now possible to evaluate and summarize results. This paper, which is the first of a series intended to cover the general subject, is devoted to herpetology. Incidentally it will serve the beginning student as a guide in investigating the herpetology of any given area. A wide range of literature on taxonomy, distribution, and life history of amphibians and reptiles has been included, so as to make possible a broad understanding of the relationship of local species to those of North America as a whole.

Many zoologists use specimens of the amphibian and reptilian fauna of the station for studies in related fields, such as parasitology and ecology. For their benefit notes are introduced on the life histories of animals observed in the area and on the location of habitats where they occur in greatest abundance. A number of papers in the literature cited will be of assistance in both field and laboratory studies.

No attempt has been made to compile a complete bibliography; in general, citations are made only of important standard works of recent date.

THE AREA OF THE BIOLOGICAL STATION

The region selected for this report is limited to Cheboygan and Emmet counties. For the most part it is a natural geographic area;

within it is all the shoreline of the northern tip of the Southern Peninsula from Little Traverse Bay to Hammond Bay. The southern line of these counties crosses the tip from Little Traverse Bay, Lake Michigan, almost to Rogers City, on Lake Huron. Bois Blanc Island (Mackinac Co.), off the northeast shore of Cheboygan County, is within the natural area. A small district near Rogers City is also outside this county.

Because of unsatisfactory winter-storage facilities only a very small collection of specimens is kept at the station, but the local fauna is fully represented at the Museum of Zoology of the University of Michigan. The taxonomy of the species here listed follows that in use at the museum.

This study has been aided by Dr. G. R. La Rue, former director of the station, and Dr. A. H. Stockard, the present director. Mrs. Helen T. Gaige, of the University of Michigan, identified specimens and read the manuscript. Many other persons, including staff members, students, and assistants, have supplied valuable material.

GENERAL LITERATURE

As a basis for the taxonomy of the amphibians and reptiles, and also as a source for English names, the recent check list of Stejneger and Barbour (1939) for these groups in North America has been used. Material on all the amphibians and reptiles known to occur in the northeastern part of North America may be found in the volumes by Pratt (1923) and Jordan (1929). The distribution of certain species in North America is treated by Schmidt in an interesting article, "Herpetological Evidence for the Post-glacial Eastward Extension of the Steppe in North America" (1938a). The journal *Copeia* is the only one covering the field exclusively. It contains many papers on the life histories of the amphibians and reptiles, together with reviews of the literature.

REGIONAL LITERATURE

In the regional literature of vertebrate fauna one may mention first *The Herpetology of Michigan* (1928), by Ruthven, Thompson, and Gaige. The authors have kindly made available to me material they have gathered for a revised edition of this booklet. Another valuable work is that by F. N. Blanchard, whose *Natural History*

of Vertebrates (1935) gives the forms and life histories of amphibians and reptiles and also contains a study of the literature.

The herpetology of the region of the Biological Station has received considerable attention. The first publication, by Ruthven (1911a), recorded the presence of fourteen species. Four more were added by Ruthven, Thompson, and Thompson (1912), and the annotated check list by Ellis (1917), who studied the ecology of the herpetological fauna, contains six not previously noted. Creaser (1928) found one new species. An article by Blanchard (1928a) lengthened the list by four, but the printer inadvertently omitted *Natrix s. sipedon*. Ruthven, Thompson, and Gaige (1928) made another addition. The present paper gives two more species known to live in the region, making a total of thirty-two.

Class AMPHIBIA

The only general taxonomic work on all the amphibia of North America is the *Batrachia of North America*, published by Cope in 1889. A more recent account of this class is Noble's *Biology of the Amphibia*, which appeared in 1931. For a classification of amphibians giving characteristics of the orders see Blanchard (1935), page 31. Moore's studies (1939, 1940 a–b, 1942) on the temperature tolerance and rates of development of the eggs of amphibia are important contributions to our knowledge of ecology and distribution.

A handbook by Logier, *The Amphibians of Ontario* (1937), and an article by Smith, "The Amphibians of Kansas" (1934), present material that enables one to make interesting comparisons with the fauna of this region.

Order Caudata — Tailed Amphibians

Four families are represented in the salamander fauna of the Douglas Lake region, three by a single genus and the fourth by but two. Only six species have been found. They are rather uniformly distributed throughout the state, and their occurrence here is of no zoogeographic importance, except that all are near the northward extension of the range of the order in eastern America. It may also be recorded that *Ambystoma tigrinum*, the only other salamander known to occur in Michigan but not collected in this region, ranges northward to Manistee County in the north-central part of the state.

The reason for its failure to extend its range is not now evident, but it is a clearly established fact that the central part of lower Michigan is the northern limit for several species of amphibians and reptiles. The range of *Ambystoma tigrinum*, however, extends into Canada in the area just to the west of Michigan.

There is no general publication on the salamanders of North America, and the special literature on the subject is widely scattered. A list of the species occurring in North America has been published by Stejneger and Barbour (1939), and keys for northeastern forms, together with descriptions of them, may be found in the works of Cope (1889) and Bishop (1943) and in the popular books by Pratt (1923) and Jordan (1929). Dunn's volume (1926) on the family Plethodontidae, which is here represented by two species, is an excellent treatment. The distribution and life history of Michigan fauna have been ably presented by Ruthven, Thompson, and Gaige (1928), who give keys for the identification of species in this region. Keys to the Michigan species, as well as life histories and a discussion of methods of research, appear in a helpful volume by Blanchard (1935). Schmidt's leaflet, *The Salamanders of the Chicago Area* (1930), covers the salamanders of this region. A fine work on the salamanders of New York, with detailed descriptions of their life histories and habits, is that by Bishop (1941), which contains a lengthy bibliography.

Several important papers on life histories of species occurring in the Douglas Lake district have been published by Dr. Blanchard and his students. They are frequently cited here in connection with names of species.

Family I. Necturidae

1. *Necturus* Rafinesque
1. *Necturus maculosus maculosus* (Rafinesque), mudpuppy

Occurrence. — Abundant. The station beach, to which many dead ones drift; boathouse; Hook Point, Sedge Point, Douglas Lake; Crooked Lake; Big Stone Bay.

Life history. — Young found in beach pools at Douglas Lake, and eggs near Hook Point, Douglas Lake; East Maple River Bridge; Indian River on Indian River; Crooked Lake in early July; and Cheboygan River near the paper mill, July 2, 1937.

Literature. — Several subspecies for North America are listed by Viosca (1937) and Stejneger and Barbour (1939). Eycleshymer (1906), Ruthven (1911b), Smith (1911a), Ellis (1917), Pearse (1921), Bishop (1926, 1932), Blanchard (1928a), Hamilton (1932), Senning (1940).

Family II. Salamandridae

2. *Triturus* Rafinesque
2. *Triturus viridescens viridescens* (Rafinesque), common newt

Occurrence. — Sedge Point Pool, Hook Point, and Douglas Lake; Fontinalis Run; Munro Lake; Mud Lake.

Life history. — Breeding aquatic forms and larvae in Sedge Point Pool in later June and early July, also Hook Point (1939). Terrestrial subadults, Sedge Point, Hook Point (1939), Smith's Bog (1939), and Munro Lake; larvae, Mud Lake. Eggs, June and July on vegetation in Sedge Point Pool. Dr. Thomas (1937) has studied this newt in connection with the life histories of certain of its parasites.

Literature. — Gage (1891), Jordan (1893), Ruthven (1911b), Pope (1924), Noble (1926, 1929), Blanchard (1928a), Morgan and Grierson (1932), Hamilton (1932), Lipsett and Piatt (1936), Thomas (1937 a–b), Reinke and Chadwick (1940), Adams (1940).

Family III. Ambystomidae

3. *Ambystoma* Tschudi
3. *Ambystoma jeffersonianum* (Green), Jefferson's salamander

Occurrence. — Rather rare. Shore of North Fish-Tail Bay, Sedge Point Pool; Smith's Bog (1939). Lake Michigan beaches in Emmet County; Duncan Bay, near Cheboygan (July 18, 1940).

Life history. — Aquatic larvae in Sedge Point Pool in July and in Bryant's Bog.

Literature. — Piersol (1910), Ruthven (1911b), Smith (1911b), Ellis (1917), Blanchard (1928a), Mohr (1931), Clanton (1934), Moore (1939).

4. *Ambystoma maculatum* (Shaw), spotted salamander

Occurrence. — Scarce. Shore of North Fish-Tail Bay, mouth of Carp Creek on Burt Lake, Maple River Cove, Nichol's Bog.

Literature. — Eycleshymer (1895), Smith (1907, 1910, 1911b), Breder (1927), Blanchard (1928a, 1930b, 1935), Moore (1939).

Family IV. Plethodontidae

4. *Plethodon* Tschudi
5. *Plethodon cinereus* (Green), red-backed salamander, dusky salamander

Occurrence. — Very abundant; Carp Creek Valley; Hook Point; Burt Lake hardwoods, and most moist woods of the region.

Life history. — Eggs in rotten logs in late June and early July. Both color phases are found in the same log. Eggs taken on June 24 hatched in the laboratory on July 15. Adults are eaten by the shrew (*Sorex cinereus*), which is abundant in this region.

Literature. — Piersol (1909, 1914), Cochran (1910), Ruthven (1911b), Ellis (1917), Dunn (1926), Blanchard (1928b, 1935), Hamilton (1932).

5. *Hemidactylium* Tschudi
6. *Hemidactylium scutatum* (Schlegel), four-toed salamander

Occurrence. — Rare. Adults in Bryant's Bog and Reese's Bog, and near Vincent Lake, June, 1935.

Life history. — Eggs, Bryant's Bog, June 20, 1925. Aquatic larvae, Bryant's Bog in summer.

Literature. — Bishop (1919), Blanchard (1922, 1923, 1928a, 1931, 1933b, 1934, 1933c), Branin (1935).

Order Salientia — Frogs and Toads

Three families of tailless amphibia exist in the region. There are five genera and ten species, two of which are very rare. Near here *Acris crepitans, Rana catesbciana, Rana palustris,* and *Pseudacris nigrita* reach the northern limits of their range. *Rana septentrionalis,* which occurs throughout the Northern Peninsula, has not been taken in the northern tip of the Southern Peninsula. *Bufo fowleri* is the only other Michigan species missing from the fauna of this area, although the sand dunes in which it is found on the west side of the state run to this region in an almost continuous line and provide an apparently suitable habitat.

There are several general works on the frogs and toads of North America besides that of Cope (1889). The taxonomy here used is that of the check list of Stejneger and Barbour (1939). Dickerson, *The Frog Book* (1907), discusses in detail the life histories and characteristics of frogs and toads. The more recent *Handbook of Frogs and Toads* (1933), by Wright and Wright, also covers the field in detail. Both of these works contain keys for the identification of Amphibia. Keys for the forms found in the State of Michigan are given by Ruthven, Thompson, and Gaige (1928), Blanchard (1935), and Schmidt (1929). Wright and Wright (1924) have published a key to the eggs of Salientia, and Wright (1929) has described the North American tadpoles.

These books contain excellent résumés of the literature on the fauna of special localities; citations from them will not be made here except when the material is especially pertinent for this region.

Family V. Bufonidae

6. *Bufo* Laurenti
7. *Bufo americanus americanus,* American toad

Occurrence. — Abundant throughout the region; found in numbers on the lake beaches and under driftwood.

Life history. — Tadpoles and transforming young in early July at Sedge Point Pool and in the pools near East Point.

Literature. — Ruthven (1911b), Ellis (1917), Blanchard (1928a), Moore (1939). On the evidence of Gaige (1932) Stejneger and Barbour (1939) list two subspecies of the common American toad. The other subspecies is found near James Bay in northern Ontario.

Mrs. Gaige reports that the record of *Bufo fowleri* for Emmet County in the Douglas Lake area as given by Ruthven, Thompson, and Gaige (1928) is an error. The most northern record is now Mason County.

Family VI. Hylidae

7. *Acris* Duméril and Bibron
8. *Acris crepitans* Baird, cricket frog

Occurrence. — Rare. Specimens on record at the University of Michigan Museum (Ruthven, Thompson, and Thompson (1912)). Recorded as very abundant in the lowland near the west side of Reese's Bog by Ellis (1917). Not taken by Blanchard or by anyone else since then.

Literature. — Not found by Blanchard (1928a). Specimens recorded by Ruthven, Thompson, and Thompson (1912) and by Ruthven, Thompson, and Gaige (1928). Now recorded by them (unpublished) as found in Michigan north to Montcalm County in southern Michigan and from Delta County in the Upper Peninsula. Wright (1931).

8. *Pseudacris* Fitzinger
9. *Pseudacris nigrita triseriata* (Wied), swamp tree frog

Occurrence. — Rare. A few specimens have been taken in the hardwoods near Burt Lake on Colonial Point; North Fish-Tail Bay (Blanchard, 1928a).

Literature. — Blanchard (1928a) records one specimen of this species as *Pseudacris feriarum.* Ruthven, Thompson, and Gaige (1928) list no specimen in the northern half of the Lower Peninsula. Wright and Allen (1908), Wright (1914), Blanchard (1935, p. 46).

9. *Hyla* Laurenti
10. *Hyla crucifer crucifer* Wied, spring peeper

Occurrence. — Fairly common in woods and near bog situations on the north shore of Douglas Lake between Sedge Point and Robert's Point; Reese's Bog; Penney Lake; Burt Lake hardwoods on Colonial Point.

Literature. — Wright (1914), Ellis (1917), Blanchard (1928a), Wright and Wright (1933).

11. *Hyla versicolor versicolor* (Le Conte) tree toad

Occurrence. — Common about camp. Often found on the cabins and under window blinds and canvas automobile covers.

Life history. — Transforming young at Smith's Bog. A number of breeding males in chorus after dark, June 20, 1927, were recorded by Blanchard (1928a). The orange-tailed tadpoles have been found in Sedge Point Pool and Bryant's Bog. Eggs taken in Sedge Point Pool, June 27, 1935, hatched in the laboratory in six days.

Literature. — Ruthven, Thompson, and Thompson (1912), Wright (1914), Ellis (1917), Blanchard (1928a), Wright and Wright (1933).

Family VII. Ranidae

10. *Rana* Linné
12. *Rana sylvatica cantabrigensis* Baird, wood frog

Occurrence. — Rather common in the bog forests on the north shore of Burt Lake; Maple River outlet; Sedge Point Pool; Burt Lake hardwoods.

Literature. — Ruthven (1911b), Wright (1914), Ellis (1917), Cummins (1920), Blanchard (1928a), Moore (1939), 1942.

13. *Rana catesbeiana* Shaw, bullfrog

Occurrence. — Now very rare; recently taken (1932–41) near Twin Lakes, Cheboygan County; Indian River; and North Fish-Tail Bay, Douglas Lake (1939). Ellis (1917) records it as very abundant along Bessey Creek in 1913 and as found near Lancaster Lake, Munro Lake, on both branches of Maple River, and at Cecil Bay, Emmet County. Not taken by Blanchard (1928a) near the station.

Life history. — Thousands of dead transforming tadpoles lay on the shore of the South Twin Lake, Cheboygan County, in late July, 1935.

Literature. — Ruthven, Thompson, and Gaige (1938) record a single specimen from the Northern Peninsula. Evidently this region is near the northward limit of its range. Wright (1914), Ellis (1917), Blanchard (1928a), Frost (1935), Pollister and Moore (1937), Thomas (1939), Moore (1939, 1942), Raney (1940).

14. *Rana clamitans* Latreille, green frog

Occurrence. — Abundant near Sedge Point Pool; Fontinalis Run; Mud Lake; and in small numbers in all suitable habitats.

Life history. — Eggs were found at Mud Lake and Sedge Point Pool, July 4, 1940, and specimens brought into the laboratory at that time of year frequently lay eggs in captivity. Green frog eggs in the gastrula stage were taken on July 22, 1940, in a quarry pool near Afton, Michigan. They were placed in a round battery jar, which at noon on July 23 reached a temperature of 29.5° C. All hatched on July 26. Tadpoles in all stages of transformation may be found in July at Sedge Point Pool, Fontinalis Run, and Hook Point.

Literature. — Ruthven (1911b), Ellis (1917), Blanchard (1928a), Thomas (1939), Moore (1939).

15. *Rana palustris* Le Conte

Occurrence. — Rare. Known only from a single location in Cheboygan County, collected by Dr. Metzelaar, which was recorded by county only and listed by Ruthven, Thompson, and Gaige (1928). One specimen only has been taken from the Northern Peninsula.

Literature. — Moore (1939, 1942).

16. *Rana pipiens* Schreber, leopard frog

The status of the name *Rana pipiens* for our local frog is in question. Stejneger and Barbour (1939) give *Rana brachycephala* for frogs in this region. Gaige, University of Michigan Museum, prefers to list it as *Rana pipiens* until a full study of the situation is made.

Occurrence. — Abundant in wet grassy places near breeding sites such as Sedge Point Pool, Maple River outlet, Hook Point; Fontinalis Run, and the north shore of Burt Lake.

Life history. — The tadpoles are found in Sedge Point Pool, Fontinalis Run, and like places. They transform in the middle of July. Force (1933) has studied the growth of the species in this region.

Literature. — Ruthven (1911b), Ellis (1917), Blanchard (1928a), Creaser and Gorbman (1939), Moore (1939), Thomas (1939), Shumway (1940).

Class REPTILIA

The only general descriptive review of the Reptilia of North America is that of Ditmars (1907, 1937), but other useful publications are the catalogue of Baird and Girard (1853) and, of recent date, the check list of Stejneger and Barbour (1939), which included the type locality and the range of each form. There is also a valuable classification of living reptiles by Blanchard (1935). The work of Stejneger and Barbour has been used as the basis for the taxonomy of the Reptilia here reported.

Large sections of several general publications are devoted to Reptilia. One may consult Stejneger (1895) for an account of the poisonous snakes of North America. Klauber (1936) and Gloyd (1940) have made special studies of the rattlesnakes. Cope (1900) describes the crocodilians, lizards, and snakes of North America. A comprehensive work is Blanchard's *Key to the Snakes of the United States, Canada, and Lower California* (1924, 1939). Another key may be found in Pope's *Snakes Alive and How They Live* (1937). Ruthven, Thompson, and Gaige (1928) give a detailed account of the Reptilia of the State of Michigan, as does Blanchard (1935). Logier's *Reptiles of Ontario* (1939) is of much comparative interest. The local lists published by Ellis (1917) and Blanchard (1928a) have notes on all species they list.

Conant's well-prepared book, *The Reptiles of Ohio* (1938), may be used to advantage in studying the many species of the Douglas Lake area. Other valuable publications on the snakes of the United States and Canada are those of Ditmars (1939) and Schmidt and Davis (1941).

Order Squamata

suborder sauria — lizards

The only general review of the lizards of North America published since that of Cope (1900) is the *Key to the Lizards of the United States and Canada* (1935), by Burt. Camp (1923) made a classification of the lizards, and Taylor (1935) studied the genus *Eumeces*, the sole genus represented in the station area. It is of interest to note that the only species recorded for Michigan occurs in some numbers throughout even the northern part of the Lower Peninsula, which is near the northern limit of its range.

Family VIII. Scincidae

11. *Eumeces* Wiegmann
17. *Eumeces fasciatus* (Linné), blue-tailed skink

Occurrence. — Not uncommon in certain small areas. Duncan Bay; Burt Lake; north end of Black Lake; Grace Harbor at Hammond Bay; and near the headwaters of Laperell Creek. For a long time in the station's history this species was known only from a single specimen collected by Ellis (1917) near the north end of Burt Lake.

Life history. — Six eggs were found on July 27, 1939, at Grace Harbor in the moist sawdust of the interior of a decaying dock log, the outer shell of which was fairly solid. Dr. Blanchard collected eggs from Duncan Bay and Grace Harbor. These he allowed to hatch, and the young were released on the station area and have been re-collected there (1935–41). They seem to be established in and about the old log laboratory, since unmarked young in their second summer were collected there on August 10, 1937.

Literature. — Ruthven (1911a), Ellis (1917), Blanchard (1928a), Noble and Mason (1933), Taylor (1935).

Suborder Serpentes — Snakes

The snake fauna of the region is composed of ten species, seven of which are not uncommon about the station and throughout the region. The failure of *Coluber constrictor flaviventris*, *Elaphe obsoleta obsoleta*, *Elaphe vulpina*, and *Thamnophis butleri*, all present in the southern part of the Lower Peninsula, to extend to this region is of zoogeographic interest.

Several of the species reach the northern limits of their range within this region, as do some of the Amphibia. These species are *Heterodon contortrix*, *Lampropeltis t. triangulum*, *Storeria dekayi*, *Thamnophis s. sauritus*, and *Sistrurus c. catenatus*.

Publications with keys and descriptions useful in the study of snakes of this region are Blanchard (1925, 1935); Ruthven, Thompson, and Gaige (1928); Pope (1937); Conant (1938); Ditmars (1939); Schmidt and Davis (1941). Walls made an interesting contribution in his paper (1940) on the eyes of snakes. Numerous life-history and taxonomic studies are cited in the present paper under the names of the species to which they refer.

Family IX. Colubridae

12. *Diadophis* Baird and Girard
18. *Diadophis punctatus edwardsii* (Merrem), eastern ringneck snake

Occurrence. — Not uncommon inside decaying logs and under driftwood along the sandy Great Lakes beaches; Big Stone Bay, Grace Harbor; Black Lake;

north end of Burt Lake; Pine Point and Grapevine Point, Douglas Lake; mouth of Carp Creek.

Life history. — The eggs are laid from early July until August in the moist interior of decaying logs on the exposed beaches and also under boards. Blanchard (1927, 1930a) has given a detailed account of the life history of this snake in this region.

Literature. — Ruthven, Thompson, and Thompson (1912), Ellis (1917), Langlois (1925), Blanchard (1928a, 1930a, 1942).

13. *Heterodon* Latreille
19. *Heterodon contortrix* (Linné), puffing adder

Occurrence. — Rare, the northern limit of its range. Though reported by Ellis in 1917 as fairly common throughout the region, in the past fifteen years it has become so rare that it is collected about the station only at intervals of several years. A very small one was found near the boathouse on June 23, 1935, and an adult at the north end of Burt Lake on July 12, 1939. Two were taken during the summer of 1942.

Literature. — Ruthven, Thompson, and Thompson (1912), Ellis (1917), Blanchard (1928a).

14. *Opheodrys* Fitzinger
20. *Opheodrys vernalis vernalis* (Harlan), smooth green snake

Occurrence. — Fairly common in grassland, in the open aspen cover, and along roads about the station.

Life history. — The eggs have been found under stones and logs along Lake Michigan beaches in late July and August. Ellis (1917) collected a set of six eggs on August 14, 1914. Blanchard (1933a) has described the eggs and young in detail.

Literature. — Ruthven (1911b), Ellis (1917), Langlois (1925), Blanchard (1928a), Dymond and Fry (1932).

15. *Lampropeltis* Fitzinger
21. *Lampropeltis triangulum triangulum* (Lacépède), milk snake

Occurrence. — Generally distributed throughout the region of the station, which is the northern limit of its range.

Life history. — Several clutches of eggs were collected by Blanchard from the interior of logs on the shore of Black Lake, and elsewhere. A female laid nine eggs in a snake box in the laboratory on July 14, 1940.

Literature. — Ruthven (1911b), Ellis (1917), Blanchard (1921, 1928a).

16. *Natrix* Laurenti
22. *Natrix sipedon sipedon* (Linné), water snake

Occurrence. — One of the most abundant snakes in this region; found along lake shores and streams and near ponds throughout the region.

Life history. — On three occasions snakes of this species have been observed along Grapevine Point catching and attempting to eat rather large individuals of *Necturus*. It is frequently seen out in the lake catching fish, and an analysis of stomach content shows that the small fish of the shore, including the dead ones of the beach drift, constitute a large part of its food. Blanchard and Finster (1933) have studied its life history, using marking methods in their experiments. Omitted from Blanchard's 1928 list.

Literature. — Ruthven (1911), Ellis (1917), Langlois (1925), Clay (1938).

17. *Storeria* Baird and Girard
23. *Storeria dekayi* (Holbrook), De Kay's snake

Occurrence. — Very rare. Taken first by Blanchard since 1928 and therefore not included in his list of that date. This is the northern limit of its range. A large specimen was collected by Miss Frances Waite at Nigger Creek on July 6, 1940, and a large one under a log on the shore of Duncan Bay on July 18, 1940. A pregnant female was taken near Duncan Bay late in June, 1941, and was held in the laboratory until August 5, when it gave birth to seven young.

Literature. — Shields (1929), Noble and Clausen (1936), Clausen (1936), Noble (1937), Conant (1938), Trapido (1939, 1940).

24. *Storeria occipito-maculata* (Storer), red-bellied snake

Occurrence. — A few are found each year. Station area; north end of Black Lake; Lake Michigan and Huron beaches. They are secretive and usually lurk under some stick, stone, board, or other cover.

Life history. — Langlois (1925) records nine young born in captivity at the station on August 20, 1923, and describes the event in detail. Blanchard (1928a, 1937), Trapido (1940).

18. *Thamnophis* Fitzinger
25. *Thamnophis sauritus sauritus* (Linné), ribbon snake

Occurrence. — Rather common in restricted habitats where grass borders a lake, pool, or stream. North Fish-Tail Bay, Sedge Point, Smith's Bog. This region is the northern limit of its range.

Life history. — The numerous young are born in late July and August.

Literature. — Ruthven (1908), Ellis (1917), Blanchard (1928a).

26. *Thamnophis sirtalis sirtalis* (Linné), garter snake

Occurrence. — Very common throughout the region.

Life history. — The very numerous young are born in late July and August. Blanchard and Finster (1933) have recorded some interesting facts on the wanderings of marked specimens near the station.

Literature. — Ruthven (1908, 1911b), Ellis (1917), Burt (1928), Blanchard (1928a), Blanchard and Finster (1933), Harrison (1933), Rahn (1940).

Family X. Crotalidae

19. *Sistrurus* Garman
27. *Sistrurus catenatus catenatus* (Rafinesque), massasauga, rattlesnake

Occurrence. — Not uncommon on Bois Blanc Island (Mackinac County) near Cheboygan; Hammond Bay in Presque Isle County; reported from Lake Huron shore east of Cheboygan and from a farm on the headwaters of Laperell Creek, Cheboygan County. Not listed by Blanchard (1928a).

Literature. — Stejneger (1895), Atkinson and Netting (1927), Creaser (1928), Klauber (1936), Schmidt (1938a), Gloyd (1940).

Order Testudinata — Turtles

No general account of all the turtles of North America has yet appeared except that found in Ditmars' *Reptile Book* (1907) and in

the revised edition, *The Reptiles of North America* (1937), which has good descriptions and some keys. An excellent work dealing with a smaller area is Pope's *Turtles of the United States and Canada* (1939). Keys for certain regions of North America have been published by Pratt (1923) and Jordan (1929). The nomenclature used here is in accordance with that of the check list of Stejneger and Barbour (1939).

Among other works of value for a study of this area are Cahn's extensive survey (1937) of the turtles of Illinois and Schmidt's illustrated leaflet (1938b) on those in the Chicago area. Schmidt's work contains a key. Species occurring in the Douglas Lake region are interestingly described in Conant's "The Reptiles of Ohio" (1938) and Babcock's *The Turtles of New England* (1919) and *Field Guide to New England Turtles* (1938) and by Lagler (1943).

At the present time the turtle fauna of the Douglas Lake region is not plentiful. Only five of the nine Michigan species are here represented, and so few specimens of two of these have been collected as to suggest that the northern limits of their abundance is somewhat to the south. The two species that are common are found throughout the Upper Peninsula.

Clemmys insculpta occurs in the Lower Peninsula northward from Muskegon and Iosco counties and in the Upper Peninsula, but intensive collecting in this region for twenty-five years failed to reveal its presence until a specimen was taken on July 1, 1936, at the north end of Burt Lake.

Sternotherus odoratus, Clemmys guttata, Graptemys geographica, and *Amyda spinifera* are confined to the southern half of the Lower Peninsula. *Terrapene carolina* may well be added to this list, and *Emys blandingii* might be included, since a few individuals are found in the Biological Station area. Their failure to occur here is an interesting problem in the zoogeography of Michigan.

Family XI. Chelydridae

20. *Chelydra* Schweiger
28. *Chelydra serpentina* (Linné), snapping turtle

Occurrence. — A few large specimens are collected each year. Carp Creek, north end of Burt Lake; Douglas Lake; Nigger Creek.

Life History. — A nest with eggs was discovered at the mouth of Fontinalis Run on the north end of Burt Lake on June 28, 1934. It had just been uncovered, presumably by a red squirrel, which left the site upon our approach. The eggs were in two and three layers. The nest was less than six inches deep,

in the moist clean sand of the beach just above the ordinary wave level and partly under a half-buried log. Most of the eggs were untouched by the discoverer, and the remains of about six more were about the place. Two months later several were opened, and two very small living embryos were found.

Literature. — Ellis (1917), Blanchard (1928a).

Family XII. Testudinidae

21. *Clemmys* Ritgen
29. *Clemmys insculpta* (Le Conte), wood turtle

Occurrence. — Very rare, one specimen taken at the north end of Black Lake on July 1, 1936, by collectors from the parasitology laboratory. It is now in the University of Michigan collection at Ann Arbor.

22. *Emys* Duméril
30. *Emys blandingii* (Holbrook), Blanding's turtle

Occurrence. — Very rare. Marl Bay (August 7, 1924), Riggsville (July 3, 1929), Maple River (late June, 1935). This region is at the northern limit of the turtle's range, although there is a record from Marquette County in the Upper Peninsula.

Literature. — Blanchard (1928a), Schmidt (1938b).

23. *Terrapene* Merrem
31. *Terrapene c. carolina* (Linné), box turtle

Occurrence. — Our only record is that of Ellis (1917), who reported collecting a specimen in the sand near the station in August, 1913. Thirty years of collecting have failed to reveal another specimen.

Literature. — Ellis (1917), Blanchard (1928a), Hildebrand (1929).

24. *Chrysemys* Gray
32. *Chrysemys picta marginata* (Agassiz), western painted turtle

Occurrence. — Very common about suitable places in the region. Sedge Point Pool, Bessey Creek; Fontinalis Run, Nigger Creek; French Farm Lake; Maple River.

Life history. — On July 1, 1938, a female was observed in the act of laying eggs in a flask-shaped hole that she had made in the side of a sand road a few feet from French Farm Lake. She was removed to the laboratory, but no eggs were laid during the summer. Destroyed nests were found on the top of the steep-sloped sand dunes near this lake.

Literature. — Ruthven (1911b), Ellis (1917), Blanchard (1928a), Bishop and Schmidt (1931, p. 134).

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PROPERTIES OF PARAFFIN RELATING TO MICROTECHNIQUE

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IN THE literature of petroleum technology, which appears to have escaped the attention of biologists, various properties of paraffin have been investigated. In spite of this work an adequate exposition of the behavior of paraffin in its microtechnical applications must involve further study. The following account relates primarily to new observations, although brief consideration will be given to pertinent aspects of the petroleum literature. Attention is directed especially to certain properties of the solid state of paraffin that are involved in microtome sectioning. Related studies on the mechanics of sectioning and on the distortions due to sectioning have appeared separately (Dempster, 1942 a–b; 1943).

Commercial paraffins are mixtures of long straight chain hydrocarbons having in common the type formula C_nH_{2n+2}. For practical purposes the term "paraffin" is applied (Gurwitsch and Moore, 1927; Berne-Allen, 1936) to mixtures containing various numbers and amounts of homologous paraffin hydrocarbons that vary in chain length from 19 to 34 carbon atoms. Mixtures of still longer hydrocarbon chains are commonly referred to as petroleum ceresins or rod waxes. The type of compounds and the amount of each that enters into a particular paraffin sample are determined by the source of the petroleum from which wax is extracted and by the processes of refining and blending. Purified hydrocarbon samples of essentially uniform molecular weight as well as synthetic paraffin hydrocarbons have been prepared, but these are laboratory rather than commercial products.

A low melting-point (m.p.) commercial paraffin consists predominantly of hydrocarbons having low melting points, whereas a high melting-point paraffin is composed of or contains a significant percentage of heavy molecule hydrocarbons of high melting point. Mixtures of long and short chain compounds show intermediate melting points. In view of the similar molecular structure, paraffin

constituents mix in all proportions, and such mixtures are characterized by a range of solidifying temperature rather than by a discrete fusion point. On fusing, paraffins tend to form solid solutions, though in certain respects, as will be discussed later (p. 255), there is some separation of heavier and lighter components.

PARAFFIN COOLING CURVES

By use of a technique similar to that outlined in the standards of the American Society for Testing Materials (A. S. T. M., 1939) data representing the cooling of paraffin in relation to time were obtained

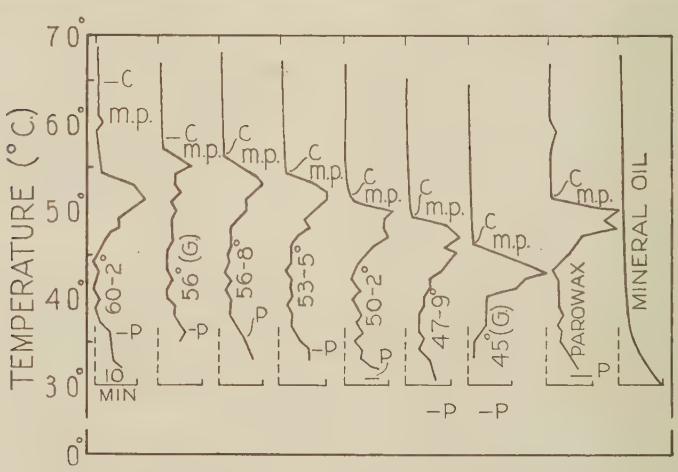

FIG. 1. Cooling curves of various types of embedding paraffins. The numbers on the curves refer to melting-point ranges indicated by the distributers. Parowax, from Standard Oil Company; 45° and 56° (G.), from Grübler; others are Bioloid of Will Corporation. *C* = cloud point; m.p. = melting point; *P* = plastic point as determined by a shearing test. The abscissa for each curve indicates the number of minutes required for a temperature drop of 1° C.

for a group of common embedding paraffins over temperatures that extended both above and below the range of solidification. These data, when plotted as the number of minutes required for paraffin to cool through each successive degree of temperature, are shown in the curves of Figure 1.

At the cloud point *C* solid paraffin begins to precipitate as a fine or feathery clouding. Shortly below this, at the melting point, the

continuing process of solidification results in the liberation of heat of fusion, and the rate of cooling becomes significantly prolonged. Technically (A. S. T. M. standards) the melting point is defined as the "temperature at which melted paraffin wax, when allowed to cool, first shows a minimum rate of temperature change." Below the melting point considerable heat is liberated, and meanwhile the ratio of solid to liquid paraffin increases until the mass finally becomes solid throughout. The humps on the curves correspond with a range of temperature of fifteen or more degrees over which large amounts of heat are dissipated. The size and the shape of the humps represent a visual measure of the quantity of heat lost and its rate of dissipation. When the paraffin mass is entirely or nearly solid, stirring of the mass, as required by the method of testing, is unsatisfactory, and the lower parts of the curves below the point of solidification are unreliable. Scott-Harley (1939) tested a number of paraffin waxes with a special method that did not involve stirring. At some point, varying ordinarily from five to ten degrees below the melting point and characteristic for each paraffin, a rapid but transitory loss of heat occurred; this heat loss presumably corresponds with the secondary peaks shown in some of the curves recorded here. This point was considered the temperature of final solidification. Ideally, deviations in the thermal curve below the solidification point are associated with peculiarities of the thermal properties of the solid state of paraffin (cf. Lord, 1939, and p. 257 of the following discussion).

THE STRUCTURE OF SOLID PARAFFIN

Several authors (Groth, 1910; Buchler and Graves, 1927; Gruse, 1928; Katz, 1930, 1932) have described paraffin crystals precipitated out of solutions of common solvents as either flat platelets or needles. These and a variety of modifications may be readily observed with the microscope; the differences in crystal structure vary with such factors as solution concentration, temperature of precipitation, and rate of solvent evaporation. Thin layers of melted paraffin, if allowed to cool slowly upon a glass surface, likewise may show needles and stratification of platelets.

Under conditions of mass crystallization, however, as in ordinary embedding procedures, certain peculiarities in crystal structure that apparently have not previously been recorded may be observed. A mass of about twenty grams of Bioloid embedding paraffin (Will

Corporation, Rochester, N. Y.) with a melting point of 50–2° C., chilled in a paper box by immersion in water of 20° C., will serve for a description of the typical paraffin structure. It will be apparent that the description applies to crystalline aggregates and not to true crystals in the physical sense of perfectly homogeneously formed bodies. A formation of complex crystalline aggregates rather than true crystals must be expected when molecules of different sorts, longer and shorter hydrocarbon chains, for instance, do not segregate to form definitive crystal types. For the sake of simplicity, however, the term "crystal" will be used in a loose sense to refer to these aggregates.

Relatively uncompressed sections of paraffin from the microtome show a mosaic of similar crystals cut in various planes. The section illustrated in Figure 1, Plate I, indicates that the crystals are rodlike or "needle-shaped," with apparently bluntly pointed or rounded ends; they may be relatively straight or may be curved; and some appear to be distorted or twisted by contiguous crystals. Two or more crystals may be fused, and sometimes branched patterns may be seen.

The crystals vary a little in size, and the more typical ones may have a cross-section diameter of a tenth millimeter and a length at least two to four times this diameter. Branching crystals approaching a millimeter in length may be found. Paraffin cooled over several hours in a Dewar flask containing warmed water produces crystals several millimeters long, with proportional increase in diameter. Rapid cooling, however, does not induce uniform formation of small crystals. Cooling of a mass of paraffin in ice water results in the formation of a peripheral zone of about two millimeters consisting of tiny crystals with a predominant orientation perpendicular to the surfaces exposed to cooling. Crystals of the peripheral one- to three-tenths millimeter are diminutive and apparently consist of both needles and plate formations. The central mass is composed of crystals variously oriented and of essentially the same size as those in masses cooled in water at 20° C. or in air at room temperature. The peripheral zone of hardened paraffin, because of its low thermal conductivity, acts as an effective insulation and permits typical crystal growth in the interior of a mass.

Characteristically, as viewed in cross section (Fig. 2, Pl. I), paraffin crystals appear to have a core area around which four to six

or more concentric lamellae of varying translucency may at times be seen. Sometimes the axial region is not clearly differentiated, but often it appears as an area ten, twenty, or more micra in diameter. In longitudinal section the central core not only traverses the length of the crystal, but in united forms appears to continue from one crystal to another. Striations running parallel to the central core and indicating the lamellar structure of the crystals are likewise evident in longitudinal section. Katz (1930) showed photographs of needle crystals precipitated from solutions of wax in which axial cores appeared; lamellation is not evident in these figures, but in some cases photographs of the ends of crystals indicate hooklike and recurrent spines in profile that are suggestive of incomplete lamellation. As seen in cross section, crystal outlines are at times deformed into five-, six-, or seven-sided figures by contiguous crystals.

If one of the poorer paraffin solvents,[1] such as amyl acetate, is flooded over a paraffin section, crystals appear as in Figure 3, Plate I. The softer paraffin is dissolved from the crystals and leaves a skeleton of harder paraffin. If the hard and soft paraffins of a mixture are indicated by *A* and *B* respectively, the concentric lamellation shown may be explained as follows: As the temperature of warm liquid paraffin is slowly lowered through the fusion range, tiny needle-like crystal nuclei of *A* form a basis for crystal growth. Heat of fusion flows from the solidified needle surface to elevate the temperature of the adjacent liquid paraffin above the melting point of fraction *B*. Only *A* precipitates on the crystal nucleus, and a crystal core is produced. More heat of fusion is liberated, and the precipitation of *B* is further delayed. When all of *A* within a convenient diffusion range has precipitated, the liquid adjacent to the core is richer in *B* than it was formerly. With *A* being added to the solid in smaller amounts, less heat of fusion leaves the needle surface, and the softer material may now lay down a lamella of wax. Heat of fusion again raises the temperature locally, so that only *A* can congeal at the crystal surface. Thus a crystal grows with alternate concentric lamellae produced by

[1] Relative solubility of 50–2° C. m.p. paraffin in a group of common solvents at 26–7° C., expressed as the number of grams of paraffin dissolved in 100 c.c. of solvent, was found to be as follows: carbon bisulphide, 78.0 g. (most active solvent); toluene, 25.0 g.; benzene, 21.5 g.; xylene, 20.8 g.; trichlorethylene, 19.0 g.; chloroform, 17.0 g.; ether, 8.8 g.; cedar-wood oil, 3.8 g.; amyl acetate, 0.9 g.; terpineol, 0.45 g.; dioxan, 0.2 g.; n-butyl alcohol, 0.1 g.; ter-butyl alcohol, 0.1 g. Paraffin of 60–2° C. m.p. was but slightly less soluble, and relative solubility followed the same order.

the alternate precipitation of hard and soft material around a needle-like core of paraffin. In a cooling melt of paraffin under routine conditions growth of individual crystals from crystal nuclei to fully formed lamellated crystals of ordinary size requires only a minute or so. Adjacent crystals increase in size till they abut on one another separated only by a thin layer at the mutual interface. Sometimes the lamellar structure at the periphery of one crystal may be definitely incorporated into the structure of the contiguous crystals.

Crystallographic examination of the different embedding paraffins studied, those indicated in Figure 1, shows them to have the same basic structure. Clear-cut lamellation was not observed in Parowax crystals. A distinctly different organization was seen only in crystals of 60–2° C. m.p. Bioloid.

The admixture of paraffin and adulterant waxes ordinarily produced crystals that could not be interpreted in terms of the crystal pattern described above. This was true of mixtures containing beeswax, bayberry wax, or high melting-point microcrystalline petroleum wax (Barnsdall Special, 160–5° F. m.p. and 180–5° F. m.p.). Mixtures containing diglycol stearate or glyceryl monostearate showed, however, a meshwork of typical though somewhat distorted paraffin crystals in the interstices of which were microcrystalline or granular stearate crystals. This is most easily seen when paraffin constitutes about half or less of the mass. Apparently — this statement is suggested by microscopic observations of wax mixtures during crystallization in a watch glass — paraffin crystals exhibit their characteristic structure in a mixture only when paraffin needle nuclei are first to appear at the cloud point. If other types of wax crystals appear first in a cooling melt, as occurs with adulterants of higher melting point, or in the 60–2° C. m.p. Bioloid, the paraffin amalgamates in crystalline masses of variable pattern; these patterns have not been studied.

Although a picture of the structure of solid paraffin may be of interest in itself, an understanding of crystal patterns is especially important since it allows one to study and analyze such plastic changes in paraffin as accompany the sectioning process (Dempster, 1942a). Likewise, the mottling or "crystallization" defect common to solid paraffin finds an explanation (p. 261).

Within the interstitial spaces of an embedded tissue — blood-vessel lumina, epithelial vesicles, interfascial clefts — paraffin crys-

tals do not show characteristic structure, even when the space is large enough to accommodate several normal-sized crystals (Fig. 1, Pl. I). Usually microcrystals or irregular lamellation, oriented in relation to tissue elements and without a definite pattern, fill the interstitial spaces. Lamellated paraffin cannot be detected within cell outlines. If a section containing tissue is observed with a polarizing microscope, the interstitial paraffin appears varicolored and brilliant, whereas tissue elements are dark (Richards, 1942). A section through paraffin-infiltrated celloidin (4 per cent) also shows darkly in polarized light; yet the celloidin has a waxy texture, and, with heat, paraffin is melted from it. It may thus be reasonably assumed that paraffin infiltrated and adsorbed on and in the cells is present in an amorphous rather than a crystalline form and hence does not show. If the pattern of paraffin congelation is modified by contiguous tissue elements, crystal growth per se would seem to be of little significance as a tissue-distorting influence. Crystals existing at the fusion range are very soft and cannot be expected to exert forces of great magnitude. During the change from the liquid to the solid state, however — that is, within the fusion range — paraffin decreases in volume by from 5 to 10 per cent (Carpenter, 1926). Under this influence infiltrated tissue would undoubtedly be subjected to collapsing and deforming strains.

TRANSITION POINTS

In an important paper Carpenter (1926) showed that certain properties of solid paraffin were different above and below a transition temperature lying $10° \pm$ C. below the melting point. Observations of mass crystallization in a clock glass, as the temperature dropped through the solidification range, showed that, after needle formation began, the paraffin acquired an initial opacity and a dull surface. Then, as the temperature dropped through a range of ten to fifteen degrees below the melting point, the mass became translucent and the surface shiny. At the transition point the coefficient of expansion suddenly increased, and the contraction in volume of cooling paraffin was momentarily arrested. Solubility of wax in acetic acid was relatively less at temperatures below the transition point than above. Air solubility in solid paraffin ordinarily was minimal at a point about ten degrees below the melting point.

Confirmatory studies on the transition point have been made, and usually both purified fractions and commercial samples entered

into the studies. Katz (1932) proved that at a temperature 5–10° C. below the melting point crystals precipitated from solutions as needles, and that below this temperature platelets were formed. Scott-Harley (1939) and Lord (1939) have found clear evidence of transition points by analyses of paraffin cooling curves. Measurements of electrical conductivity by Jackson (1935) showed a transition point ten to fifteen degrees below the melting point. Müller (1932), using X-ray analysis, measured lattice dimensions of paraffins over the thermal range between room temperature and the melting points of the paraffins tested. Transition points characterized by a change from one type of molecular symmetry to another were seen.

Each variety of paraffin has a discrete and characteristic transition point that may be somewhat closer to or farther from the melting point than the transition points of other paraffins. The differing properties above and below the transition temperature are considered to be due to changes in the molecular or microcrystalline structure of the paraffin constituents. These changes are probably effected by alterations in the positions of hydrogen atoms relative to the carbon atoms of the hydrocarbon chains — changes akin to those recognized in stereoisomers. In some cases transition points are not evident; sometimes a mixture of two samples, each showing transition points, is not characterized by a transition point.

Carpenter described a change in crystal form from needles to platelets as wax in a clock glass changed from the opaque to the translucent form. This change is readily seen if the surface of a melt is studied microscopically during congelation. Microtome sections through the surface of such a mass disclose a mosaic of lamellated plates rather than the typical needles described above; one or two millimeters deeper, however, sections reveal typical lamellated needles. The transition from needles to plates thus appears to be a surface phenomenon limited to the mesh of superficial needles that are oriented in a plane at the surface. Below the surface crystals are indifferently oriented and do not coalesce to form a new crystal pattern.

PARAFFIN PLASTICITY

Plastic deformation may be defined as a change in the shape of a solid without the appearance of rupture or discontinuity, occurring as a response to a deforming force (i.e. greater than the gravity

effects due to the weight of the material itself) and persisting after the force has been discontinued. A substance that is easily molded by a small force or is more extensively deformed by a larger one is relatively more plastic than a more resistant material. To say that paraffin exhibits a high degree of plasticity means that, at some temperature under consideration, paraffin as contrasted with some other material is readily and permanently molded without the occurrence of fractures by the application of a stated tensile, compressive, or shearing force.

Temperature is an important condition in considering plastic changes. A stick of warm paraffin stretches like taffy; a similar stick at room temperature may break without apparent necking. Similarly, below some critical temperature, paraffin compresses but little with loading; at a higher temperature the same load causes a noticeable distortion (Dempster, 1942a). The difference between the plastic properties of paraffin is brought out most strikingly, however, by a shearing test.

A large block of clear paraffin about fifteen millimeters thick and with flat sides is clamped between vise jaws with three millimeters of the upper block edge projecting. A metal rod with a square cross section is placed so that it straddles both vise jaws at 90° and held so that a plane face is forward and perpendicular to the vise jaws (Fig. 2). When the rod is shoved forward along the vise jaws all the projecting paraffin is scraped away. If the paraffin, vise, and rod have been maintained at a testing temperature until an even temperature has been established and if a constant speed of rod movement is obtained, either of two types of chip is produced (Fig. 2). Above a critical temperature a thick, compressed, and relatively smooth-surfaced chip is produced; below, a segmented chip, made of transverse prisms with a serrated upper surface, is formed. The temperature of transition between one and the other of the types of chip, which on repeated testing varies not more than a half degree, may be called the plastic point.

On the curves of Figure 1, *P* indicates the plastic points of the different paraffins as tested by this method. These points do not bear a constant relation to the melting points of the respective paraffins, though the low melting-point paraffins in general have lower plastic points than the high melting-point paraffins do. Paraffins of 45°C. and 47–9°C. m.p. have the same plastic point; the 60–2°C. m.p., 56°C. m.p., and 56–8°C. m.p. paraffins have a com-

mon high plastic point; the 53–5° C. m.p. paraffin is but slightly lower, and the 50–2° C. m.p. paraffin is intermediate between the higher and the lower values. What is particularly significant is that the plastic points correlate better than melting points with curves representing the degree of compression of microtome sections (Dempster, 1943). Paraffins with similar plastic points are similarly compressed by the microtome knife, and those with high plastic points are compressed less than paraffins with lower plastic transition points. This correla-

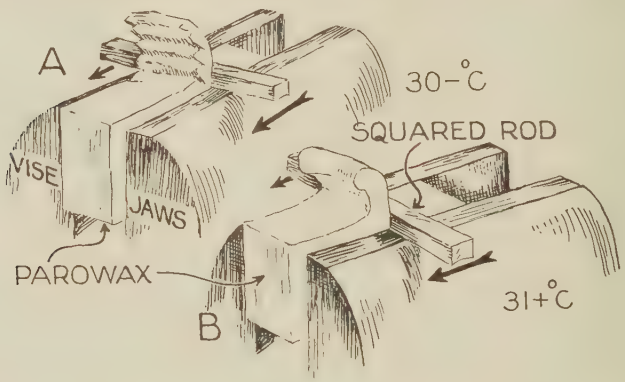

Fig. 2. Types of paraffin chip removed in a shearing test. Sketch A shows the type of chip produced at temperatures below the plastic transition point; sketch B, the suddenly changed character of a chip at a slightly higher temperature

tion will explain an observation of Aumonier (1938) that a paraffin of higher melting point produced more compressed microtome sections than a paraffin of lower melting point.

It is assumed tentatively, in the absence of data on transition temperatures for the paraffins dealt with here, that plastic points are dependent on the changes in paraffin that occur at characteristic transition temperatures, but that energy supplied by the testing forces results in plastic manifestations at a temperature (plastic point) actually lower than the true transition point.

Plastic point, determined by some such method as that mentioned, should, if the method is suitably standardized, be of much more value to microscopists as a practical correlate with sectioning behavior of paraffins than the melting-point data now used.

THE CONGELATION OF PARAFFIN

It is a standard embedding procedure to cool a solidifying mass rapidly, and it is assumed that such cooling prevents "crystallization," that is, produces an amorphous mass or reduces the size of crystals significantly. This assumption is based (Kappers, 1907) on analogies with the crystallization of metals and electrolytes in which thermal conductivity is high and in which solidification occurs at a discrete temperature rather than over a fusion range. In metals the intercrystalline junctions are harder than the crystalline material proper (Rosenhain and Haughton, 1935) and exert greater stress to distorting forces. A metal composed of small crystals and having a proportionately large number of intercrystalline junctions is different in its properties from the same metal composed of large crystals; in paraffin, however, intercrystalline junctions are soft, and readjustments in a mass under stress occur in large part at such regions (Dempster, 1942a). There is no evidence of work hardening in paraffin, as contrasted with metals, and a thoroughly kneaded mass of paraffin showing little evidence of structural organization sections like a freshly cast mass. It is thus questionable whether small crystals of paraffin, or amorphous paraffin, have any advantage in microtechnique over larger ones. If each crystal is contiguous with all adjacent crystals so that no interstices remain, the paraffin will be clear and homogeneous; such a mass will react in a uniform manner to deforming forces such as those of the sectioning process.

As Carpenter (1926) has shown, clear solid paraffin may contain from seven to fifteen volumes of air dissolved in one hundred volumes of paraffin. If the air is completely dissolved and is evenly distributed through a mass, the paraffin should be clear. The so-called "crystallization" of paraffin, as the term is used by microscopists, appears to be the naked-eye visualization of crystals — a mottling effect due to intercrystalline discontinuities or air spaces. This defect appears if air or volatile solvents are thrown out of solution during the congelation of paraffin or if paraffin is stressed at temperatures well below the melting point, i.e. stress opacity (Nádai, 1931; Dempster, 1942a). Petroleum oils may remain in some paraffins owing to inadequate refining and are an unavoidable source of mottling.

Congelation during routine paraffin embedding may be visualized as follows: Air dissolved in liquid paraffin is trapped within the

mass when a congealed film appears at the surface. At the solid periphery of such a mass some air is released (because of minimal solubility in the paraffin just congealed) to be redissolved primarily in the still liquid region. Contraction (i.e. reduction in volume) of the solid periphery initially increases the pressure on the enclosed fluid mass, and this should enhance air solubility. The solid peripheral zone grows in thickness with further congelation. Contraction, occurring primarily at the interface between the solid and the liquid phases, results in a decreased total volume of the mass, and a compensatory depression of the surface layer of congealed paraffin begins. As this layer becomes thicker and at the same time more resistant to contracting forces, the liquid interior of the mass is then subjected to decreasing pressures. Such pressure will tend to volatilize dissolved air from the liquid phase at the core of the paraffin mass, and the central region may show air-filled intercrystalline spaces and visible mottling after complete solidification. The peripheral zone, if not stressed too much by contraction forces, is clear. Cooling of a mass of paraffin by immersion in cold water, after a congealed film has formed over the surface of the melted paraffin, has often been recommended, but, it may be inferred from the foregoing discussion, rapid cooling provokes increased mottling.

Routine embedding procedures too commonly allow the introduction of the mottling defect, and when mottling occurs, especially when discontinuities of the matrix are close to embedded tissue, crumpled and defective sections result. Procedures that eliminate mottling or reduce it to an insignificant amount are the following: (1) Small bits of tissue (2–3 mm. diam.) may be embedded in small buttons, a gram or less, of paraffin slowly pipetted to a glass plate. Mottling defects are negligible for very small masses of paraffin, since the solid surface layer is never too thick or tough to compensate fully for contraction. (2) Larger pieces of tissue may be embedded in a somewhat deep container of paraffin if the mass is cooled from the bottom while the surface is kept fluid by playing a hot spatula over it. This allows the escape of air that is released during the solidification process. (3) A considerable excess of paraffin may be used during embedding in a tall vessel, and the mass may be cooled, chiefly from the bottom. This method provides an excess of liquid in which released air might dissolve. On solidification all but the lower part of the mass containing the tissue may be cut away to be reused later;

the matrix surrounding the tissue is clear of mottling. This procedure like that in (2) is somewhat slow, and the paraffin crystals may be definitely larger than those in smaller masses cooled more rapidly. (4) Precooling of larger bits of infiltrated tissue in air may be followed by immersion in a container of molten paraffin. When the mass is cooled from below, mottling of the matrix is so far away from the tissue that the defect is of no importance.

SUMMARY

Unadulterated paraffin when congealed in an embedding mass is composed of contiguous needle-like crystalline aggregates, each of which consists of a central core and many concentric lamellae made of alternate depositions of hard and soft paraffin. This crystalline mass forms the matrix for embedded tissue. Except for the most peripheral layer rapid cooling of a mass does not materially reduce the size of crystals. If each crystal is in intimate contact with other crystals so that no interstices occur, the paraffin is clear and homogeneous, and good microtome sections may be made. Mottling or "crystallization" is a defect due to air spaces between crystals, which makes crystals visible grossly. Suggested procedures that eliminate or reduce mottling are outlined. Within tissue interstices typical needle structure of paraffin is supplanted by irregular lamellation, but within cells the paraffin is amorphous. Cooling curves are presented to show characteristics of a group of typical embedding paraffins. The literature on paraffin transition points is cited in relation to a discussion of the plastic behavior of paraffin. Above and below a characteristic temperature for each paraffin the mode of response to a distorting force becomes altered. This temperature, for standardized conditions of testing, may be called the plastic point, and it may be used as a measure of the relative hardness of paraffin. The sectioning behavior of paraffin is more closely related to the plastic point of a sample than to the melting point.

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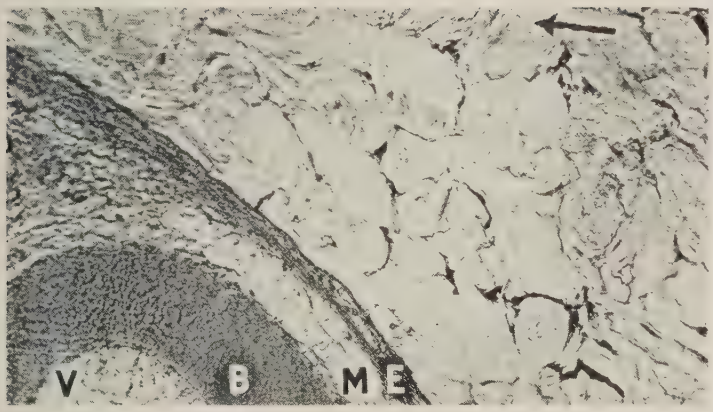

FIG. 1. Photomicrograph of a paraffin section from the microtome (12-micron section; 56–58° C. m.p. Bioloid paraffin; × 90). The mosaic to the right shows crystals cut crosswise, obliquely, and longitudinally. Within the embryo tissue at the left (as at *V* or *M*, for instance) paraffin crystals are small and are altered. Abbreviations: B, brain wall; E, epidermis; M, mesenchyme; V, ventricle of brain. The arrow indicates the direction of knife movement in the making of the section

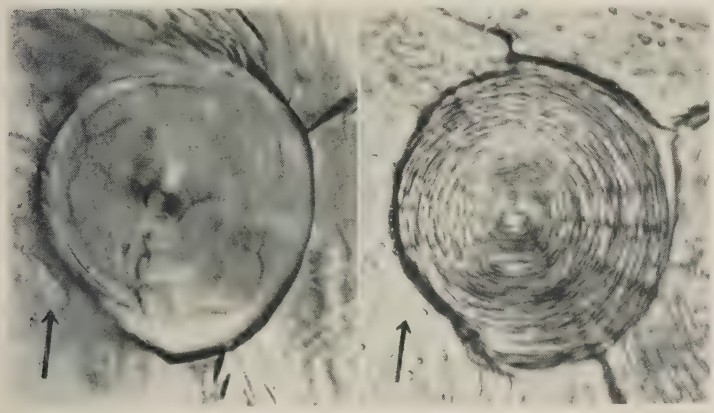

FIG. 2 FIG. 3

FIG. 2. A cross section of a relatively undistorted paraffin crystal (50–52° C. m.p. Bioloid paraffin; 25 μ) showing a central core and a suggestion of concentric lamellae. × 500

FIG. 3. The same crystal after flooding with amyl acetate. Lamellation of hard paraffin is shown

THE THREAD-WAISTED WASPS (HYMENOPTERA–SPHECINAE) OF MICHIGAN, WITH KEYS AND DISTRIBUTION

ROBERT R. DREISBACH

THE subfamily Sphecinae, commonly called thread-waisted wasps, belongs to the family Sphecidae and the superfamily Sphecoidea.

The Sphecoidea are separated from the other superfamilies, except the Apoidea, by two characters, namely: (1) The pronotum is developed on the dorsal lateral margin into lobes called tubercles; (2) The posterior margin of the pronotum never touches the tegulae. This superfamily may be distinguished from the Apoidea, or bees, by the hind tarsi, which are slender and in which the first joint is not broadened or thickened, and by the simple unbranched hairs. The Sphecinae in particular can be segregated from the bees by virtue of their petiolate abdomen.

The Sphecidae differ from the other families of the Sphecoidea by the presence of a prepectus, which distinguishes them from the Bembecidae and the Cerceridae; by the absence of an elongate process on the mesosternum; and by the slender femora, which separate them from the Ampulicidae. The petiole of the abdomen and the large body size at once make it easy to separate the subfamily Sphecinae from the other subfamilies of the Sphecidae.

Keys, descriptions, and synonymy (with two exceptions) for this subfamily as found in North America are given in the literature cited at the end of this paper.

The two exceptions in the synonymy noted above apply to the species *Chlorion rubidorsum* (Costa) and the subgenus *Ammobia*. Dr. H. T. Fernald, in his *The Digger Wasps Belonging to the Subfamily Chlorioninae*, 1906, refers to *C. rubidorsum* (Costa) as *C. bifoveolatum* (Taschenberg). In a communication to the writer he cites the reference to the original description as follows: "*Enodia rubidorsum* Costa, *Ann. Mus. Zool. Napoli*, I, 1862, p. 69." The name "Am

mobia," used in this paper for a subgenus of Chlorion, is given as "Proterosphex" in Dr. Fernald's paper. Further study of this genus convinced him that "Ammobia" is the proper name.

In comparing the number of species and varieties of Sphecinae reported in Michigan with records for other states we find 28 species and varieties listed for Michigan, 19 for New York, 19 for Connecticut, 23 for New Jersey, and 26 for North Carolina. In addition to the 28 species and varieties actually collected there are 7 more species which, to judge from their present known distribution, most certainly will be captured in Michigan at some future date, and for this reason they are inserted in the keys.

The thread-waisted wasps of Michigan are divided into three tribes and five genera, as follows:

Tribe I. Chlorionini — genus *Chlorion* (and subgenera).
Tribe II. Sphecini — genera *Podalonia* and *Sphex*.
Tribe III. Sceliphronini — genera *Chalybion* and *Sceliphron*.

The sexes are easily distinguished in this group, as they are in most of the Hymenoptera. The males have 13-jointed antennae and 7 dorsal abdominal segments, and the inner margins of the eyes are strongly converging. The females have 12-jointed antennae and 6 dorsal abdominal segments, and the inner margins of the eyes are for the most part parallel. The sting and the male genitalia, if exserted, also separate the sexes at a glance.

Some of the principal technical terms used in the keys are:

Prepectus, a narrow area along the anterior margin of the episternum of the mesothorax, just behind the tubercles and just below the tegulae, bounded posteriorly by a suture.

Stigmatal groove, a groove extending from the insertion of the petiole to the ventral end of the stigma, or spiracle. This groove passes just dorsal to the swelling above posterior coxa and curves upward to the stigma.

Mesepimeron, a narrow plate extending from just below the insertion of the hind wings to the posterior coxa.

Mesopleuron, the broad plate just below the insertion of the front wings.

Metapleuron, the lateral plate of the metathorax, lying just above and parallel to the mesepimeron.

Metanotal flange, a thin, almost membranous process, with a texture similar to that of the tegula. It starts below and extends back of the hind wing on the metanotum. It is best seen from the side with the wings in normal resting position.

Species marked with an asterisk (*) have not yet been collected in this state.

KEY TO THE MICHIGAN GENERA OF SPHECINAE

1. Second cubital cell receiving only the first recurrent vein; third cell receiving second recurrent vein; claws with one to six teeth near base; tibiae spinous; tarsal comb present in female except in subgenus Isodontia ..... Tribe Chlorionini, *Chlorion*
1. Second cubital cell receiving both recurrent veins, or second recurrent vein interstitial with second transverse cubital 2

2. Claws simple without a tooth beneath; tarsal comb present in female; abdomen generally very elongate, petiole of one or two segments; cubital vein of hind wings usually originates beyond transverse median vein Tribe Sphecini 3
2. Claws with single minute tooth beneath, rarely without tooth; tarsal comb absent in female; abdomen with one-segmented petiole; cubital vein in hind wings interstitial (or nearly so) with transverse median vein; metathorax with large U-shaped area above Tribe Sceliphronini 4

3. Petiole consisting of two linear segments; comb teeth on hind tibial spine closely packed together, slender; spiracle on second petiole segment (first abdominal segment) at or behind middle ..... *Sphex*
3. Petiole consisting of one segment; dorsal plate of first abdominal segment more or less bell-shaped; comb teeth on hind tibial spine not crowded, stout; spiracle on first abdominal segment in front of middle, at least not behind middle, of segment ..... *Podalonia*

4. Species black and yellow, not metallic; clypeus flat, usually bidentate at apex; petiole of abdomen about twice as long as metathorax; transverse median vein in front wings not interstitial with basal vein, but uniting with median vein a little before origin of basal nervure *Sceliphron*
4. Species metallic blue or violaceous; clypeus usually tridentate anteriorly; petiole of abdomen not longer than metathorax; transverse median vein in front wings interstitial with basal vein ..... *Chalybion*

KEY TO THE MICHIGAN SPECIES OF THE GENUS *CHLORION*

1. Second cubital cell of fore wing higher than broad 2
1. Second cubital of fore wing as broad as or broader than high 8

2. Claws with one tooth ..... Subgenus *Chlorion* 3
2. Claws with two or more teeth 4

3. Body bright blue or green ..... *C. cyaneum* Dahlb.
3. Body bronze blue ..... *C. cyaneum aerarium* Patton

4. Claws with two teeth, clypeus with median truncated lobe and sinus on each side ..... Subgenus *Palmodes* 5
4. Claws with three to six teeth; clypeus with median emargination Subgenus *Prionyx* 7

5. Abdomen black or at most only faintly brownish .. *C. laeviventris* (Cress) *
5. Abdomen more or less ferruginous or yellow 6

6. Tip of abdomen black ..... *C. abdominalis* (Cress)
6. Abdomen entirely ferruginous or yellow; wings fuliginous; female with six comb teeth ..... *C. rufiventris* (Cress) *

7. Abdomen more or less ferruginous or yellow; ventral plate of sixth abdominal segment of male excavated on posterior margin *C. rubidorsum* (Costa) *
7. Abdomen black or dark brown; ventral plate of sixth abdominal segment of male not excavated as in preceding species .. *C. atratum* (Lepel)

8. Stigmatal groove absent ..... Subgenus *Isodontia* 9
8. Stigmatal groove present ..... Subgenus *Ammobia* 11

9. Mandible with two teeth ..... *C. aztecum* (Sauss) *
9. Mandible with three teeth 10

10. Legs black ..... *C. harrisi* Fernald
10. Legs more or less yellow ..... *C. auripes* Fernald

11. Abdomen black; wings dark with violet reflections *C. pennsylvanicum* (L.)
11. Abdomen mostly red, with apical segments black .. *C. ichneumoneum* (L.)

KEY TO THE MICHIGAN SPECIES OF THE GENUS *SPHEX*

1. Females 2
1. Males 19

2. Collar long or short, but transversely ridged 3
2. Collar short, smooth 4

3. Medium to large species; meso- and metapleural pubescent bands strong, not sericeous ..... *S. procerus* (Dahlb.)
3. Medium to small species; meso- and metapleural pubescent bands weakly pubescent, pleura whitish sericeous ..... *S. politus* (Cress) *

4. Propodeal side ridges running strongly forward 5
4. Propodeal side ridges running slightly or not at all forward 6

5. Thorax and pleura dull black; pleura rough between punctures; veins of wings, especially anterior part, deep yellow, apical part clouded; propodeal side ridges running strongly forward *S. placidus placidus* (Sm.)
5. Thorax and pleura glossy, shining; pleura smooth between punctures; veins of wings yellowish; propodeal side ridges running forward on anterior part only ..... *S. fernaldi* Murray

6. Wing veins light golden yellow, except that costa is dark-colored from just in front of stigma to its terminus ..... *S. harti* Fernald
6. Wing veins not yellow 7

7. Episternal suture with backward notch, forming a horizontal V *S. aureonotatus* (Cam.)
7. Episternal suture not forming such a notch 8

8. Episternal suture short, ending about opposite prothoracic lobe 9
8. Episternal suture long, extending well down toward under side of body 13

9. Legs partly red; scutellum practically without ridges .. *S. aberti* (Hald.) *
9. Legs entirely black; scutellum longitudinally ridged 10

10. Metanotal flange large, reddish; prothoracic lobe, lower sides of collar, streaks on the meso- and metapleura, and large spot in front of middle coxa, reddish; eyes convergent below ..... *S. leopardus* Fernald
10. Metanotal flange small or absent; prothoracic lobe and rest of thorax black; eyes converging only slightly below 11

11. Tegula reddish yellow; base of wing yellowish except subcosta; thorax evenly and generally pubescent on sides; strong meso- and metapleural bands present ..... *S. junceus* (Cress)
11. Tegula black; base of wing not yellowish; thorax only slightly pubescent; mesopleural pubescent band narrow; metapleural pubescent band absent 12

12. Very slight metanotal flange; base of costa of fore wing amber in reflected light ..... *S. kennedyi* Murray
12. No metanotal flange; base of costa in fore wing black in reflected light *S. urnarius* (Dahlb.)

13. Legs partly ferruginous; thorax densely pilose *S. breviceps breviceps* (Sm.) *
13. Legs black 14

14. Collar rising almost vertically from neck, then turning backward to form a rather long, almost flat, dorsal surface; no metanotal flange; scutellum longitudinally ridged ..... *S. arvensis* (Dahlb.)
14. Collar rising slopingly from neck to highest point; dorsal surface much shorter 15

15. Pilosity of head and thorax black 16
15. Pilosity of thorax white, although head pilosity may be black 17

16. Wings light yellow on basal half, somewhat fuliginous on apical half; first abdominal segment and about one half of second red, remainder of abdomen black ..... *S. fernaldi* Murray
16. Entire wings deep fuliginous; second abdominal segment mainly red, with posterior border black ..... *S. nigricans* (Dahlb.)

17. Head pilosity black; inner margin of eyes parallel; no metanotal flange *S. mediatus* (Cress)
17. Head pilosity white; inner margin of eyes slightly converging below; a moderate metanotal flange 18

18. Pleura with sericeous hairs short and inconspicuous *S. pilosus* subsp. *nudus* Murray
18. Pleura heavily sericeous ..... *S. pilosus* subsp. *pilosus* Fernald

19. Episternal suture with a backward notch forming a wide horizontal V; clypeus with a sharp tooth ..... *S. aureonotatus* (Cam.)
19. Episternal suture running straight downward, no notch 20

20. Episternal suture extending only to or just below the prothoracic lobe . 21
20. Episternal suture extending down to under side of body 27

21. Collar long, broad, flat above, transversely ridged, rising rather sharply from neck ..... *S. procerus* (Dahlb.)
21. Collar shorter, not flat above, not turning back at a sharp angle 22

22. Pilosity of thorax black ..... *S. fernaldi* Murray
22. Pilosity of thorax white 23

23. Clypeal margin broadly truncate, sometimes with weak central emargination; legs partly ferruginous ..... *S. aberti* (Hald.) *
23. Clypeal margin not broadly truncate, always with central emargination 24

24. Metanotal flange very large, reddish; prothoracic lobe, lower sides of collar, streaks on meso- and metapleura, and a large spot in front of middle coxa, reddish; eyes convergent below ..... *S. leopardus* Fernald
24. Metanotal flange small or absent; prothoracic lobe and pleura entirely black 25

25. Mesonotum entirely smooth, no transverse ridges; costa of fore wing amber in reflected light; first (second petiole segment) and second abdominal segment red, remainder of abdomen entirely black without bluish tint; no metanotal flange ..... *S. kennedyi* Murray
25. Mesonotum with a few transverse ridges, although it may be almost smooth; costa of fore wing black in reflected light; first two or three abdominal segments may be red, remainder of abdomen black with bluish tint; no metanotal flange 26

26. First and second abdominal segments red with black dorsal band, remainder of abdomen black; mesopleural pubescent band grading into sericeous in front; metapleural band weakly developed *S. urnarius* (Dahlb.)
26. First, second, and third abdominal segments red, generally with a black dorsal band, remainder of abdomen black; mesopleural pubescent band heavy, sharply defined; metapleural pubescent band well developed *S. junceus* (Cress)

27. Collar finely transversely ridged ..... *S. politus* (Cress) *
27. Collar smooth or with only faint traces of ridges 28

28. Entire body clothed with black hairs throughout 29
28. Entire body not clothed with black hairs throughout 31

29. Wings strongly tinged with yellow, both veins and surface between the veins; hyaline to beyond the cells, the outer part partly fuliginous; dull black ..... *S. placidus placidus* (Sm.)
29. Wings more or less fuliginous; more or less shining 30

30. Wings somewhat fuliginous; body shining, glossy between the punctures; clypeus shining, with a few punctures ..... *S. fernaldi* Murray
30. Wings strongly fuliginous; body between punctures not glossy, hardly shining, dull; clypeus dull, more heavily punctured *S. nigricans* (Dahlb.)

31. Collar rising almost vertically from the neck, then turning backward to form an almost flat long dorsal surface; head pilosity black *S. arvensis* (Dahlb.)
31. Not as in preceding, collar rising slopingly from neck to highest point; head pilosity white 32

32. Legs partly ferruginous ..... *S. breviceps breviceps* (Sm.) *
32. Legs black 33

33. Wing veins yellow; metanotal flange moderately large .. *S. harti* Fernald
33. Wing veins dark brown to black; metanotal flange very small 34

34. Pleura with sericeous hairs short and inconspicuous *S. pilosus* subsp. *nudus* Murray
34. Pleura more or less heavily sericeous .... *S. pilosus* subsp. *pilosus* Fernald

KEY TO THE MICHIGAN SPECIES OF THE GENUS *PODALONIA*

1. Females 2
1. Males 5

2. Abdomen entirely black; without a metanotal flange ... *P. luctuosa* (Sm.)
2. Abdomen red and black or entirely red 3

3. Metanotal flange very large, with strong emargination; clypeus bulging only slightly in center, with many punctures, but these separated by several times their diameter; mesepimeron without transverse striae except traces just before posterior edge. ..... *P. violaceipennis* Lepel
3. Metanotal flange small or, if large, without a strong emargination; clypeus strongly bulging in center 4

4. Mesopleuron with a great many tiny punctures, surface glossy; more or less conspicuous short brownish hairs on surface of mesopleuron; abdomen red and black or, rarely, entirely red ..... *P. sericea* Murray
4. Mesopleuron with very few tiny punctures, surface not glossy; brownish sericeous hairs if present inconspicuous ..... *P. robusta* (Cress)

5. Metanotal flange very large, with strong emargination; pilosity of head and thorax black; abdomen red and black ..... *P. violaceipennis* Lepel
5. Metanotal flange large, small, or none, but if large, without strong emargination; pilosity of head black but pilosity of thorax may be white 6

6. No metanotal flange; pilosity of head and thorax black; clypeus broadly transverse ..... *P. luctuosa* (Sm.)
6. Metanotal flange present; clypeus narrowly transverse; at least part of pilosity of thorax generally white 7

7. Mesopleuron glossy, with abundant white sericeous hairs; metapleuron and mesepimeron without prominent transverse ridges *P. sericea* Murray
7. Mesopleuron not glossy, and with few or no sericeous hairs; metapleuron and mesepimeron with prominent transverse ridges .. *P. robusta* (Cress)

The genera *Sceliphron* and *Chalybion* consist of but a single species each, namely, *S. caementarium* (Drury) and *C. cyaneum* Klug., respectively.

The distribution records are taken from insects in the museums of the University of Michigan and Michigan State College, the collections of Mr. George Steyskal, Mr. Curtis Sabrosky, and the author.

As is usual in the distribution records of insects, there are no

specimens from a good part of the territory covered. Nor are there records of the collection of Sphecinae from the thirteen following counties: Iron, Menominee, Delta, Arenac, Sanilac, Shiawassee, St. Clair, Barry, Eaton, Cass, Branch, Hillsdale, and Lenawee. Eleven more counties are represented by only one species. On the other hand, Midland County is represented by 18 of the 28 species and varieties; Oakland, by 15; Washtenaw and Huron, by 13; and Cheboygan, Manistee, Ingham, and Berrien, by 12 each. There have been collected 15 species in the Upper Peninsula, 24 in the Lower Peninsula, and one on Isle Royale. Two species, *Sphex arvensis* (Dahlb.) and *S. pilosus* subsp. *pilosus* Fernald, have been found only in the Upper Peninsula. *Chlorion auripes* Fernald, *C. cyaneum* Dahlb., *C. cyaneum aerarium* Patton, *C. harrisi* Fernald, *C. ichneumoneum* L., *C. pennsylvanicum* L., *Sphex aureonotatus* Cam., *S. leopardus* Fernald, *S. nigricans* (Dahlb.),* and *S. placidus placidus* (Sm.) have been collected only in the Lower Peninsula. The remainder have been taken in both the Upper and the Lower peninsulas.

ANNOTATED LIST OF SPECIES AND VARIETIES

Chlorion abdominalis (Cress). — Dates of capture: July 6 to August 9. L. P.:[1] Cheboygan, Crawford, Roscommon, Iosco, Osceola, Muskegon, Wayne.

Chlorion atratum Lepel. — Dates of capture: July 16 to September 5. U. P.:[1] Schoolcraft and Mackinac. L. P.: Cheboygan, Charlevoix, Alpena, Benzie, Kalkaska, Crawford, Alcona, Manistee, Missaukee, Iosco, Mason, Osceola, Gladwin, Oceana, Midland, Huron, Gratiot, Lapeer, Ingham, Livingston, Oakland, Van Buren, Kalamazoo, Jackson, Washtenaw.

Chlorion auripes Fernald. — Dates of capture: July 20 to August 22. L. P.: Midland, Livingston, Oakland, Washtenaw, Wayne.

Chlorion cyaneum Dahlb. — Dates of capture: June 13 to August 25. L. P.: Gratiot, Allegan, Berrien.

Chlorion cyaneum aerarium Patton. — Dates of capture: July 26 to September 5. L. P.: Manistee, Wexford, Lake, Midland, Kalamazoo, Washtenaw, Wayne.

Chlorion harrisi Fernald. — Dates of capture: June 12 to Septem-

[1] L. P., Lower Peninsula; U. P., Upper Peninsula.

ber 3. L. P.: Cheboygan, Crawford, Manistee, Wexford, Roscommon, Iosco, Lake, Osceola, Clare, Gladwin, Oceana, Midland, Huron, Saginaw, Clinton, Genesee, Ingham, Livingston, Oakland, Washtenaw, Wayne, Berrien.

CHLORION ICHNEUMONEUM L. — Dates of capture: July 6 to September 21. L. P.: Manistee, Lake, Clare, Gladwin, Oceana, Isabella, Midland, Huron, Ottawa, Genesee, Ingham, Livingston, Oakland, Kalamazoo, Calhoun, Jackson, Washtenaw, Wayne, St. Joseph.

CHLORION PENNSYLVANICUM L. — Dates of capture: July 24 to September 12. L. P.: Iosco, Midland, Bay, Huron, Genesee, Ingham, Livingston, Oakland, Kalamazoo, Jackson, Washtenaw, Wayne, St. Joseph.

SPHEX ARVENSIS (Dahlb.). — Dates of capture: July 15 to August 29. U. P.: Dickinson, Chippewa.

SPHEX AUREONOTATUS Cam. — Dates of capture: July 9 to September 5. L. P.: Midland, Ingham, Oakland, Wayne, Berrien.

SPHEX HARTI Fernald. — Dates of capture: July 3 to September 23. U. P.: Chippewa. L. P.: Leelanau, Manistee, Midland, Huron, Saginaw, Ingham, Oakland, Wayne, Berrien.

SPHEX JUNCEUS (Cress). — Date of capture: August 23. H. T. Fernald, in his work on North American and West Indian digger wasps of the genus *Sphex*, says this species has been collected in Michigan.

SPHEX KENNEDYI Murray. — Dates of capture: June 13 to September 24. U. P.: Gogebic, Mackinac. L. P.: Cheboygan, Presque Isle, Alcona, Manistee, Iosco, Mason, Osceola, Midland, Bay, Huron, Montcalm, Gratiot, Saginaw, Oakland, Van Buren, Washtenaw, Berrien.

SPHEX LEOPARDUS Fernald. — Dates of capture: July 21 to September 14. L. P.: Midland, Oakland.

SPHEX MEDIATUS (Cress). — Dates of capture: July 2 to September 2. U. P.: Keweenaw, Baraga, Marquette, Schoolcraft, Luce, Chippewa. L. P.: Cheboygan, Roscommon.

SPHEX NIGRICANS (Dahlb.). — Dates of capture: June 19 to August 9. L. P.: Allegan, Oakland, Kalamazoo, Washtenaw, Wayne, Berrien.

SPHEX PILOSUS subsp. NUDUS Murray. — Dates of capture: July 3 to September 24. Isle Royale. U. P.: Dickinson, Marquette, Alger, Chippewa, Mackinac. L. P.: Charlevoix, Lapeer.

Sphex pilosus subsp. pilosus Fernald. — Date of capture: August 2. U. P.: Ontonagon.

Sphex placidus placidus (F. Smith). — Dates of capture: September 3 to 21. L. P.: Oakland, Washtenaw, Wayne.

Sphex procerus (Dahlb.). — Dates of capture: June 2 to September 27. U. P.: Schoolcraft, Mackinac. L. P.: Cheboygan, Charlevoix, Otsego, Montmorency, Benzie, Grand Traverse, Crawford, Oscoda, Manistee, Wexford, Roscommon, Lake, Osceola, Gladwin, Oceana, Midland, Huron, Muskegon, Ionia, Ingham, Oakland, Jackson, Washtenaw, Berrien.

Sphex urnarius (Dahlb.). — Dates of capture: May 10 to September 25. U. P.: Baraga, Dickinson, Marquette, Alger, Schoolcraft, Mackinac. L. P.: Cheboygan, Presque Isle, Charlevoix, Leelanau, Antrim, Otsego, Montmorency, Benzie, Kalkaska, Crawford, Oscoda, Alcona, Manistee, Roscommon, Ogemaw, Iosco, Lake, Osceola, Clare, Gladwin, Oceana, Mecosta, Isabella, Midland, Bay, Huron, Muskegon, Gratiot, Saginaw, Ionia, Genesee, Lapeer, Ingham, Oakland, Van Buren, Kalamazoo, Washtenaw, Wayne, Berrien, St. Joseph.

Podalonia luctuosa Sm. — Dates of capture: May 13 to September 20. U. P.: Dickinson, Marquette, Schoolcraft, Chippewa, Mackinac. L. P.: Cheboygan, Charlevoix, Wexford, Mason, Lake, Osceola, Isabella, Midland, Huron, Gratiot, Saginaw, Lapeer, Ingham, Oakland, Wayne.

Podalonia robusta (Cress). — Dates of capture: June 26 to September 25. U. P.: Keweenaw, Gogebic, Alger, Chippewa, Mackinac. L. P.: Cheboygan, Otsego, Benzie, Grand Traverse, Kalkaska, Crawford, Manistee, Missaukee, Ogemaw, Midland, Huron, Saginaw.

Podalonia sericea Murray. — Dates of capture: July 4 to August 21. U. P.: Chippewa. L. P.: Van Buren, Berrien. The specimen from Van Buren County is a paratype and is in the University of Minnesota collection.

Podalonia violaceipennis (Lepel). — Dates of capture: May 29 to September 7. U. P.: Chippewa, Mackinac. L. P.: Cheboygan, Charlevoix, Leelanau, Kalkaska, Alcona, Manistee, Missaukee, Osceola, Gladwin, Midland, Huron, Kent, Ingham, Van Buren, Calhoun, Wayne.

Sceliphron caementarium (Drury). — Dates of capture: June 30

to September 1. U.P.: Baraga, Mackinac. L. P.: Cheboygan, Charlevoix, Grand Traverse, Crawford, Manistee, Roscommon, Iosco, Oceana, Midland, Bay, Huron, Montcalm, Tuscola, Genesee, Ingham, Livingston, Oakland, Macomb, Van Buren, Kalamazoo, Jackson, Washtenaw, St. Joseph, Monroe.

CHALYBION CYANEUM Fab. — Dates of capture: June 1 to August 17. U. P.: Mackinac. L. P.: Cheboygan, Grand Traverse, Manistee, Newaygo, Midland, Huron, Montcalm, Gratiot, Saginaw, Genesee, Lapeer, Ingham, Macomb, Van Buren, Kalamazoo, Calhoun, Washtenaw, Wayne, Berrien.

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BANDING AS AN AID IN STUDYING THE ACTIVITIES OF THE LITTLE BROWN BAT, *MYOTIS LUCIFUGUS LUCIFUGUS* *

HAROLD B. HITCHCOCK

ALTHOUGH bats are by no means uncommon in Michigan, much remains to be discovered about their activities. Where, for example, do the hundreds of little brown bats that form colonies in buildings during the summer pass the winter? Is it the same bat that we always find behind the cottage shutter? How far do bats wander during their nocturnal feeding flights? These are just a few of the things about which little is yet known. Bats of the commonest species, *Myotis lucifugus lucifugus*, are easily caught in almost any neighborhood where there are buildings, and they can be permanently marked by means of numbered bands. Using this technique Griffin (1940) learned about the homing abilities and migrations of bats in the New England area; Mohr (1934) conducted similar work in Pennsylvania, employing fingerling tags. Hitchcock and Reynolds (1942) studied homing of banded bats in Ontario, across the border from Michigan.

During the summer of 1942 an opportunity was afforded to the writer to study bats at the Biological Station of the University of Michigan, at Douglas Lake, Cheboygan County. With the exception of one specimen of *Myotis keenii septentrionalis*, all those captured were of the species named above. In all ninety were tagged with bird bands issued by the Fish and Wildlife Service of the Department of the Interior, Washington, D.C. The bands were clamped around the hind leg, where apparently they cause no inconvenience or injury.

The easiest place in which to collect bats at the Station is behind the shutters of the faculty cabins, especially after the middle of August. Here they can be reached from the ground and gathered

* This study was made through the coöperation of the University of Michigan Biological Station at Douglas Lake, Cheboygan County, Michigan.

by hand. Another haunt is in the roof of one of the automobile shelters, where some could usually be extracted by means of forceps from cracks between the beams, and squeakings indicated many more out of sight between the ridgepole and the roofing. A small colony was located in the door of one of the cabins, where a sprung piece of metal sheathing permitted access to a narrow space behind the boards. At the very close of the season a colony was discovered in the attic of the caretaker's residence, where forty, representing perhaps half of the population at the time, were captured.

The first banding was done on July 24, when two adult males and one adult female were caught behind the shutters of faculty cabins. Both males were subsequently recaptured twice in the same area; the female was retaken once.

The next banding was done on August 20, when 19, including 2 of the first lot, were caught behind the shutters. The increase was due to the addition of young individuals, the distribution being as follows: adult male, 1; adult female, 3; young male, 7; young female, 8. On this occasion the bats were released not at the Station, but near Petoskey, about sixteen miles in a straight line from Douglas Lake. They were carried there by car and freed on the afternoon of August 21. On August 23, when the next collecting was done, one of these bats, a young male, was recaptured behind the shutter of a faculty cabin. The only other bat from this group that is known to have returned was found on August 31 behind the same shutter where it had been first captured on July 24.

Homing experiments previously reported have dealt with bats captured either in colonies or in caves, and have demonstrated that both immature and adult bats are able to home for distances considerably greater than those recorded here. The present experiment is of interest, however, in showing that they will return to an area even after scattering from the colony. Little is known of the speed of homing, so that the fact that one came back before the third night is of some interest. It is unfortunate that the last opportunity of making a complete roundup of bats was on August 24, soon after the closing of the Station. During the last week of August Professor Charles W. Creaser made several inspections of shutters still in place, and on the 31st recovered one of the bats that had been released at Petoskey, as noted above.

On August 24 all the known hiding places of bats at the Station

were visited, and fifty were collected. These were taken 325 miles by car and released on August 25 near Port Sanilac, Michigan, some 185 miles from Douglas Lake in a straight line. It will be interesting to check over the bats at the Station this summer (1943) to see whether any of the lot return to their old haunts.[1]

Because all the bats handled were banded, information on their whereabouts during the winter may be gained. The little brown bat is known to hibernate in subterranean retreats. Caves and passages in abandoned mines frequently shelter them by the hundreds. Since there are no caves near Douglas Lake, bats of this species summering there probably migrate. Do they go to caves in Indiana, or in Missouri, where large numbers hibernate? Bats from the Biological Station may help to answer this question if someone collects a banded specimen and reports the place and date of capture to the Fish and Wildlife Service.

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[1] These studies were continued during the summer of 1943 by Miss E. Mohrmann, working under Dr. C. W. Creaser. None of the bats banded in 1942 were recaptured, but some seventy-five new specimens were tagged.

A CHECK ON THE FIN-CLIPPING METHOD FOR ESTIMATING FISH POPULATIONS *

LOUIS A. KRUMHOLZ

THE first instance of marking fish for experimental purposes is recorded by Izaak Walton in *The Compleat Angler* (1653). According to him, Sir Francis Bacon studied the age and homing instincts of salmon "by tying a riband, or some known tape or thread, in the tail of some young Salmons which have been taken in weirs as they have swimmed towards the salt water; and then by taking part of them again, with the known mark, at the same place, at their return from the sea, which is usually about six months after." Since his time there has evolved the use of button, strap, and belly tags as means of identification.

Calderwood (1902) indicated that Fraser marked salmon in 1829 by removing the adipose fin. Fin clipping as a means of marking fish has been employed extensively in studies of salmon, trout, and other fresh-water fish, mostly, however, in determining migration, growth, and survival of plantings.

Recently David H. Thompson, of the Illinois Natural History Survey, used fin clipping as one of the procedures in making an estimate of the population of black crappies, *Pomoxis nigro-maculatus* (LeSueur), in Lake Senachwine, a backwater of the Illinois River, near Henry, Illinois. It is unfortunate that the results of these experiments and a description of the technique employed have not been published. Underhill (1941) used the same formula as Thompson in determining the size of a breeding population of chub suckers, but marked the fish by removing two or three adjoining scales from the side. Thompson's procedure (slightly modified) has been employed by the Michigan Institute for Fisheries Research in making population estimates of four Michigan lakes, but only on Twin Lake in Oscoda County was it feasible to check the method by poisoning.

* Contribution from the Institute for Fisheries Research of the Michigan Department of Conservation.

METHODS

During the first part of the check on Thompson's method the anal fin was clipped. Later the left pectoral, instead of the anal fin, was removed. The fins were cut about one-eighth inch from the flesh to lessen risk of infection and because the mark was intended to last only for the duration of the experiment. All fish taken in the nets each day were weighed, measured, marked, and returned to the water at a central station, indicated by a buoy (Thompson did not

FIG. 1. Net A, special fyke net for trapping small fish

release the fish at a central station), to afford equal opportunity for the dispersal of the fish in any direction. Marked fish that were subsequently taken in nets were recorded as "returns" and again released at the central station. Those marked fish that died in the nets were also regarded as returns, and were subtracted from the total number of marked fish in the lake. Any of these fish that were found dead outside the nets were not counted as returns, but were subtracted from the number of marked fish. A complete circuit of the shoreline in quest of dead fish was made twice each day. No fish were marked during the last ten days of net operation.

Four different sizes of fyke nets, designated by the letters A, B, C, and D in the text, with the same letters indicating their locations in

the lake (Fig. 2), were used in the population study of the north basin of Twin Lake.

Net A. — A special fyke net, developed in Wisconsin for trapping small fish, equipped with two galvanized pipe frames five feet wide and four feet deep at the front (Fig. 1). The first frame has a vertical center bar for attachment of the lead. Four other hoops are wooden, and each has a diameter of four feet. The lead was 150 feet long and four feet deep. The entire net and lead was hung with three-eighths-inch square mesh and treated with copper oleate.

Net B. — A large tarred fyke with a front hoop diameter of four feet hung with one-inch square-mesh netting. It was equipped with wings twenty feet long and four feet deep, with one and one-half-inch square mesh. A lead one hundred feet long and four feet deep with two-inch square mesh was used with this net.

Net C. — A small tarred fyke of one-inch square mesh with a three-foot front opening, with twenty-foot wings of one and one-half-inch square mesh. A fifty-foot lead was used with this net.

Net D. — A small fyke with a three-foot front opening equipped with twenty-foot wings. The entire net was hung with three-eighths-inch square netting and treated with copper oleate. No lead was used with this net.

DESCRIPTION OF TWIN LAKE

Twin Lake, which consists of two basins, is located in T. 25 N., R. 2 E., Section 25, about eight miles south and two miles west of Mio, Michigan. The north basin, which was used for the experiment, is about seven and three-quarters acres in extent and has a maximum depth of thirty-five feet (Fig. 2). It has a rather definite sandy shoreline, and the deeper parts of the bottom are covered with pulpy peat. The slope of the basin is rather steep, except at the south end. Many trees that have fallen into the water or were dropped there in lumbering have become water-soaked and are found nearly everywhere along the shoreline. These deadheads restricted the setting of nets to some extent and made seining impracticable. Aquatic plants were fairly abundant in the shallow areas.

The south basin (10.1 acres), somewhat larger than the north basin, has a maximum depth of forty feet. The shoreline is more irregular than that of the north basin, but the bottom types of the two depressions are quite similar. There are many deadheads around

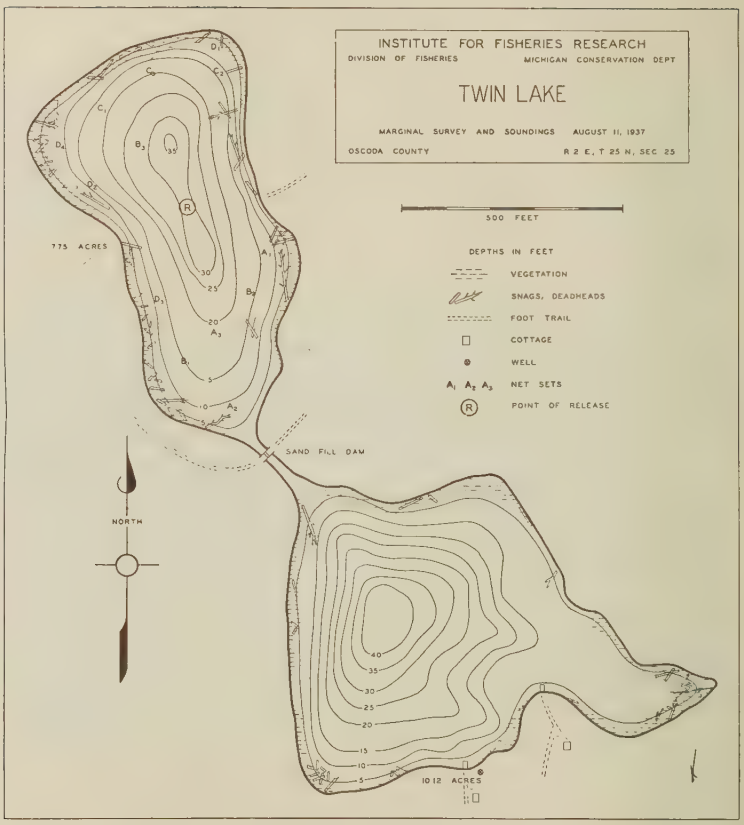

FIG. 2. Twin Lake, Oscoda County, Michigan (outlines and depth contours taken from a map by the United States Forest Service)

the shore of the south basin also, but the aquatic vegetation was not so abundant as that in the north basin.

The Huron National Forest kindly provided Civilian Conservation Corps labor, under the direction of Mr. Gifford Adams, to construct a barrier dam between the two basins during March and April, 1941. An eight-foot opening was left in the middle of the dam to allow free passage of the fish from one basin to the other prior to the poisoning. The central opening of the dam was filled in on August 28.

PROCEDURE

The nets were set in the locations indicated in Figure 2. All sets were made with the lead running diagonally from the shore. The nets were moved and reset as follows: original set, on July 29 (A_1, B_1, C_1, and D_1 on the map); second set, on August 6 (A_2, etc.), after the nets had had time to dry; second change, on August 13 (A_3, etc.), with nets again allowed time to dry before resetting; an additional change with net D, on August 20.

The number of fish caught, the number marked, and the number of returns are shown in Table I. These data furnished the material for an estimate of the population of the fish over forty-five millimeters in total length. Those of a smaller size passed through the meshes of the nets and therefore could not be included in the estimate.

The mathematics of the method of making an estimate of the total fish population that Thompson used has been described by Schnabel (1938, formula 2). It can be proved algebraically that this formula gives yields that are high, but correction for this error is too laborious to be considered practicable. The formula we used, as modified from Schnabel, is $P = \frac{\Sigma \cdot A \cdot B}{\Sigma \cdot C}$, in which P is the population, A is the number of fish examined on any one day, B is the number of marked fish in the lake, and C is the number of returns.

Investigations that involve the use of marked fish in netting operations are subject to certain uncontrollable errors. Some of the more frequent causes of error are: (1) Fish marked during the experiment may die or may be caught by anglers; (2) The gear may be so selective as to limit the size of the fish taken; (3) The duration of the experiment may be so short as to give misinformation; and (4), If the investigation is extended over a considerable time, small fish will grow to a size large enough to be taken by the nets.

The opening in the middle of the dam between the two basins allowed fish to pass freely from one to the other. Observations at various times during the investigation showed that they actually passed both out of and into the north basin, and it is assumed that the movement was approximately equal and did not have any marked effect on the population estimate.

An intensive creel census, during which the entire catch of each fisherman was examined at the end of the day's fishing, was in

TABLE I

DATA AND ESTIMATE OF THE TOTAL POPULATION OF FISH OVER FORTY-FIVE MILLIMETERS IN LENGTH OF THE NORTH BASIN OF TWIN LAKE, OSCODA COUNTY, MICHIGAN, JULY 29–AUGUST 23, 1941

Date	A	Number of fish marked	Number of marked dead fish	B	Product A · B	Sum of products	Number of returns	C	Estimated population
	Number of fish examined			Number of marked fish in lake				Sum of returns	
July									
30	53	53	..	..	...	....	..	..	...
31	55	53	..	53	2,915	2,915	2	2	1,458
August									
1	67	64	..	106	7,102	10,017	3	5	2,003
2	59	55	..	170	10,030	20,047	2	7	2,864
4	85	75	3	225	19,125	39,172	6	13	3,013
5	94	79	..	297	27,918	67,090	3	16	4,193
6	53	50	..	376	19,928	87,018	1	17	5,119
7	115	109	15	426	48,990	136,008	5	22	6,182
8	59	56	3	520	30,680	166,688	4	26	6,411
9	53	49	13	573	30,371	197,059	4	30	6,567
11	53	46	51	609	32,277	229,336	5	35	6,552
12	68	63	1	604	41,074	270,410	2	37	7,308
13	45	41	2	666	29,970	300,380	4	41	7,326
14	38	37	..	705	26,790	327,170	..	41	7,980
15	45	..	..	742	33,390	360,560	3	44	8,195
16	28	..	..	742	20,776	381,336	..	44	8,667
18	40	..	1	741	29,640	410,976	2	46	8,934
19	20	..	..	741	14,820	425,796	..	46	9,256
20	30	..	..	741	22,230	448,026	5	51	8,785
21	27	..	..	741	20,007	468,033	1	52	9,001
22	42	..	..	741	31,122	499,155	1	53	9,418
23	20	..	..	741	14,820	513,975	..	53	9,698

operation on both basins of the lake during the whole summer. The census clerk was instructed to take added precaution in checking in order that accurate records of any fish marked during the experiment caught by anglers might be accounted for in the compilation of the population data. Inasmuch as no marked fish were recorded in the anglers' catches, there was no loss by this means. No allowance was made in the estimate for unmarked fish either caught by anglers or found dead in the lake.

The nets used were very selective. Nets A and D caught many small fish, but only a few large ones. On the other hand, nets B and C could not retain fish as small as those netted by A and D, but caught about 80 per cent of all fish taken during the study. Net B, although the mesh size was considerably larger than that of net A, caught more fish than the combined catches of the three other nets. It has been suggested by Van Oosten (1935) that fishes may react negatively to darkness and therefore avoid an impounding net darkened by small meshes. The data from the fish taken in all nets were lumped together on the assumption that the differences in the catches of the individual nets would counteract one another and would give a fairly reliable estimate of the population.

On August 29, 1941, the waters of the north basin of Twin Lake were treated with powdered derris root (5 per cent rotenone). The powder was mixed into a thin suspension and poured over the surface waters in the wake of an outboard motor in accordance with the technique developed by the Michigan Institute for Fisheries Research (Eschmeyer, 1937; Greenbank, 1941). In addition to the application of derris to the surface waters, a new method of introducing the chemical into the deeper waters was tried with satisfactory results. The apparatus consisted of a ten-inch funnel attached by the small end to a five-eighths-inch garden hose. Two ten-pound sash weights were used to keep this end of the hose well under water. A fifteen-gallon drum fitted with a five-eighths-inch spigot was set in the middle of the boat and the hose attached. The drum was filled with a suspension of derris, and the boat was moved over the deeper parts of the lake. The suction caused by the inverted funnel and the forward motion of the boat pulled the suspension out of the drum into the deep water. The process of dispersion in deep water was rather slow owing to the small diameter of the hose and the relatively great amount of friction. A hose three-fourths to one inch in diameter would be more satisfactory than the one used in the experiment.

The water temperature at the surface was 70° F. at 8:45 A.M., when the application of derris was begun, and distressed fish were seen rising at various points within fifteen minutes. Two thirds of the derris was applied to the surface and one third was put in the deeper water. The application was completed by 12:45 P.M.

Individual lengths, weights, and scale samples were taken from

TABLE II

NUMBER AND WEIGHT IN POUNDS BY SPECIES OF FISHES HAVING A TOTAL LENGTH GREATER THAN FORTY-FIVE MILLIMETERS RECOVERED FROM THE NORTH BASIN OF TWIN LAKE AFTER TREATMENT WITH DERRIS*

Date	Largemouth Bass		Bluegill		Pumpkinseed		Bluegill × pumpkinseed hybrids		All fish	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
August										
29	107	31.56	3,470	247.25	155	11.63	83	13.38	3,815	303.82
30	20	3.88	1,320	54.31	50	3.25	17	2.00	1,407	63.44
31	24	5.63	3,002	99.56	94	6.56	34	5.19	3,154	116.94
September										
1	3	0.88	638	38.88	10	0.88	5	1.25	656	41.89
2	1	0.31	374	21.75	6	0.50	5	1.31	386	23.87
3	3	0.56	78	6.63	2	0.25	...	.....	83	7.44
4	1	0.12	46	4.00	1	0.12	...	.....	48	4.24
5	...	.....	33	2.12	...	.....	...	.....	33	2.12
6	...	.....	11	0.75	...	.....	...	.....	11	0.75
7	...	.....	11	0.94	1	0.12	...	.....	12	1.06
Totals	159	42.94	8,983	476.19	319	23.31	144	23.13	9,605	565.57

* In addition there were 1,773 miscellaneous fry less than 45 mm. long having a total weight of 11.88 pounds.

all the largemouth black bass, *Huro salmoides* (Lacépède), recovered and from representative samples of bluegills, *Lepomis m. macrochirus* Rafinesque, pumpkinseeds, *Lepomis gibbosus* (Linnaeus), and bluegill × pumpkinseed hybrids. These were the only kinds of fish in the lake. The fish for which individual data were not taken were counted and weighed. A complete pickup of all dead fish was continued for ten days after the poisoning. Table II shows the numbers and weights of those recovered.

DISCUSSION

Table III gives the numbers and percentages of the fish of different size groups taken during the netting and poisoning operations. The figures for netting are for the aggregate catches of all four nets. It is evident that the nets were selective, since most of the fish were more than one hundred millimeters in total length.

Estimates of the populations of the individual species and the numbers of each taken during the poisoning are given in Table IV. The numbers collected by means of poisoning do not corroborate

TABLE III

NUMBER AND PERCENTAGES OF FISHES OF DIFFERENT SIZES IN SAMPLES TAKEN BY NETTING AND POISONING FROM THE NORTH BASIN OF TWIN LAKE, OSCODA COUNTY, MICHIGAN

Total length millimeters	Mean length inches	Netting		Poisoning	
		Number of fish	Percentage	Number of fish	Percentage
Bluegills					
0–50	1.6	15	2.3	87	6.7
51–100	3.1	97	14.7	274	21.1
101–150	5.0	235	35.8	614	47.3
151–200	6.7	287	43.6	286	22.1
201–250	8.2	22	3.3	36	2.8
251–300	10.4	2	0.3	..	..
Pumpkinseeds					
0–50	1.3	1	0.4	8	2.5
51–100	3.1	19	7.5	121	38.5
101–150	5.0	177	70.2	141	44.9
151–200	6.5	54	21.4	38	12.1
201–250	8.4	1	0.4	6	1.9
Largemouth black bass					
51–100	2.9	3	12.0	21	11.5
101–150	4.5	5	20.0	26	14.4
151–200	6.6	13	52.0	38	20.9
201–250	9.0	4	16.0	82	45.0
251–300	10.5	..	..	11	6.0
301–350	13.2	..	..	4	2.2
Bluegill × pumpkinseed hybrids					
51–100	3.1	3	3.2	12	9.0
101–150	5.4	23	24.8	19	14.2
151–200	6.7	67	72.0	99	73.8
201–250	8.1	..	..	4	3.0
All fish					
0–50	1.6	16	1.5	95	4.9
51–100	3.1	122	11.9	428	22.2
101–150	5.0	440	42.8	800	41.5
151–200	6.7	421	41.0	461	23.9
201–250	8.9	27	2.6	128	6.7
251–300	10.5	2	0.2	11	0.6
301–350	13.2	..	..	4	0.2
Totals		1,028		1,927	

TABLE IV

Estimates of Populations of Individual Kinds and the Number of Each Recovered during the Poisoning in the North Basin of Twin Lake, Oscoda County, Michigan

Data are given only for fish over forty-five millimeters long.

Species	*Estimated population*	*Fish recovered during poisoning*
Largemouth black bass	51	159
Bluegills	16,832	8,983
Pumpkinseeds	1,360	319
Bluegill × pumpkinseed hybrids	837	144
Totals	19,080	9,605

the individual population estimate for any one species. Had the nets been fished for a longer time and had special effort been made to catch only one species, the individual estimates would probably have been much closer. The investigation was intended to give a total-population estimate only of fish over forty-five millimeters in total length.

The total population as estimated from the netting operations was 9,698 fish as compared with 9,605 taken in the poisoning. There is no way of knowing how nearly complete the recovery of poisoned fish was inasmuch as many fish, particularly small ones, may sink at once to the bottom and disintegrate there. Fortunately the preferred habitat of small fish is along shore, so that recovery of a large percentage is possible if one is careful. Some dead fish are eaten by reptiles, birds, and mammals. In this investigation 86 per cent of all marked fish assumed to be alive in the lake were recovered in the poisoning. Prior to the poisoning some of the marked ones might have escaped through the open channel into the south basin, and some might have died without being recovered. The total population of fish more than forty-five millimeters in total length as estimated in Table I is only one per cent higher than that found by means of the poisoning.

The estimate from netting operations was very close to that obtained by poisoning in this first check on the fin-clipping method for estimating fish populations. Further studies of this type are needed to prove definitely the accuracy of the method. At the present time the supply of rotenone-containing roots has been drastically

curtailed because of the war, and no suitable substitute has been found. Other checks of this method will be made when conditions permit.

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NATURAL ENEMIES OF CRAYFISHES IN MICHIGAN *

KARL F. LAGLER AND MARY JANE LAGLER

IT IS the purpose of this paper to bring together records of specific predator and prey relationships for the crayfishes of Michigan and to point out, so far as possible, the interactions of vulnerability and distribution, habitat, and habits. It is generally known that crayfish are of considerable importance in the food chains of a large number of animals representing the principal vertebrate classes. Moreover, there are noteworthy differences in the degree of this importance among the various predators and in life-history stages of certain of them. Some of the natural enemies of crayfish are economically significant; others have little or no such moment. It is clearly demonstrable, however, that crayfish not only contribute directly to our resources but by their incidence in the food of fish-eating vertebrates also buffer valuable food and game fishes that might otherwise be "destroyed."

The taxonomy of crayfish and notes on their distribution and ecology in the present paper are from Creaser (1931). Many of the identifications were made by Dr. Karl E. Goellner, who also kindly read the manuscript and made suggestions for its improvement. Names of fish are from Hubbs and Lagler (1941); of amphibians and reptiles, from Stejneger and Barbour (1936); of birds, from Van Tyne (1938); and of mammals, from Burt (MS). In accordance with ornithological practice the vernacular names of birds are regarded as equivalent to technical names when begun with capital letters.

Information given here on specific interrelations between vertebrates and crayfishes is largely from food studies based on analyses of the contents of digestive organs or of droppings and is mostly original. Data for the snakes and the fish-eating birds are from the publications or manuscript reports on fish predation by the senior author, in collaboration with J. Clark Salyer, II.

* Contribution from the Department of Zoölogy, University of Michigan.

SPECIFIC RELATIONSHIPS

Of special interest are the exact relationships of predators to particular prey species. Parasitologists and students of the natural history of crayfishes will find here answers to many questions and clues to others that they have directed to us. Workers in fish management may obtain indications helpful in choosing crayfishes best suited for introduction into waters where they are lacking. The choice will obviously be those species that are most abundant, exhibit a wide habitat range, and show desirability as fish food and ability to protect preferred fish species from common enemies by buffering. The decapod species will be taken up individually and relationships based on actual records disclosed.

Of the eight species of crayfish that are recorded for Michigan only five figure in the food of vertebrates. The other three species (*Cambarus rusticus*, *C. fodiens*, and *C. blandingii acutus*) are uncommon in those habitats from which our predator material has been obtained and, so far as we know, are not eaten by any higher animal in the area. One of these, *C. fodiens*, is a burrowing species, and its vulnerability to vertebrate predation is reduced by its fossorial habit.

Cambarus virilis Hagen

Cambarus virilis has a wide distribution in Michigan, being known from all the major drainages. Although occurring abundantly in both lentic and lotic habitats, it is reported to have a preference for streams in which there are stones that provide hiding places. It inhabits both trout and nontrout waters. In all its places of abode it is subject to predation by many animals; those for which we have records are listed and discussed below.

Fishes. — *C. virilis* has been found to compose only a small amount of the food of 11 spotted gars (*Lepisosteus productus*) from lakes in the southern part of the state (Lagler, Obrecht, and Harry, 1943). It is perhaps of even less importance in the food of longnose gars (*Lepisosteus osseus oxyurus*), occurring only once in 136 specimens from southern Michigan (Lagler and Hubbs, 1940). The lower incidence in the latter gar species is probably due to the fact that the longnose gar is less well adapted to the bottom-feeding habit requisite for capturing crayfish than is the spotted gar, which has a shorter, broader snout; neither of these gars is by any means a regular bottom

feeder. By contrast, *C. virilis* is very prominent in the food of the bowfin (*Amia calva*) in the same region. A total of 67 was present in 204 bowfins (Lagler and Hubbs, 1940; Lagler and Applegate, 1942); they indicate a particular vulnerability of crayfish to a bottom-feeding predacious fish.

Although we have records of crayfishes in the food of three species of trout, none are for *C. virilis*. It may be assumed, however, that because of its general availability it is eaten by the common brook trout (*Salvelinus f. fontinalis*), the brown trout (*Salmo trutta fario*), and the coast rainbow trout (*Salmo gairdnerii irideus*).

C. virilis is one of the crayfishes often eaten by basses; both large-mouth bass (*Huro salmoides*) and smallmouth bass (*Micropterus d. dolomieu*) prey on it.

Amphibians. — No specimens of *C. virilis* were found in a large series of mudpuppies (*Necturus maculosus*) from a lake in southern Michigan (Lagler and Goellner, 1941). It seems probable, however, that bottom-feeding *Necturus* are predators of this crustacean, particularly in such habitats as the Huron River near Dexter, Michigan, where both occur.

Reptiles. — Examination of a large series of water snakes (*Natrix s. sipedon*) from all over the Lower Peninsula has failed to show this crayfish in the food. Numerous garter snakes (*Thamnophis s. sirtalis*) collected about lakes, ponds, and streams also contained none, although they very often held fish.

Larger aquatic turtles as a group are feeders upon crayfishes (Lagler, 1943). Two specimens of *C. virilis* were identified among the remains of several crayfishes eaten by 113 musk turtles, mostly from lakes in southern Michigan. The snapping turtle (*Chelydra serpentina*) contained 127 crayfish of this species in 323 specimens from over the entire state, and 66 Blanding's turtles (*Emys blandingii*) from the Lower Peninsula held 36. It is attacked sparingly by the Midwestern painted turtle (*Chrysemys picta marginata*); only two were found in 413 individuals. Perhaps a more common predator is the spiny soft-shelled turtle (*Amyda s. spinifera*), since two specimens of *C. virilis* were present in only 15 of them. The species was not identified among the crayfishes eaten by the geographic turtle (*Graptemys geographica*), and it is not known that they are preyed upon by the spotted turtle (*Clemmys guttata*) or the wood turtle (*Clemmys insculpta*).

Birds. — Several birds eat crayfish extensively. These crustaceans are of very great import to mergansers (Salyer and Lagler, 1940). Both the American Merganser (*Mergus merganser americanus*) and the Hooded Merganser (*Lophodytes cucullatus*) feed upon *C. virilis*, particularly in winter. It was especially numerous in the food of American Mergansers from the shallow waters of Saginaw Bay, where it abounds. Other records that we have are for the American Bittern (*Botaurus l. lentiginosus*), Eastern Green Heron (*Butorides v. virescens*), Great Blue Heron (*Ardea h. herodias*), American Golden-eye (*Bucephala clangula americana*), and the Eastern Belted Kingfisher (*Megaceryle a. alcyon*).

Mammals. — Although several fur bearers in the state are natural enemies of *C. virilis*, there are actual predation records for only one, the otter (*Lutra c. canadensis*), reported by Lagler and Ostenson (1942). Indications are that this crayfish is readily available to the otter in trout-stream habitats, even in winter. These streams ordinarily do not freeze over in winter, and otter easily obtain crayfish from their hiding places under stones. Other probable mammalian predators of *virilis* are the opossum (*Didelphis v. virginiana*), raccoon (*Procyon l. lotor*), and mink (*Mustela vison*).

Cambarus immunis Hagen

Cambarus immunis is known from scattered locations in the Lower Peninsula. It is most abundant in stagnant shallow waters, but also occurs in lakes and slow-moving streams. Habitat preference is a water area with a soft bottom in which it may partially bury itself. This choice of environment strikingly reduces incidence as prey of several animals which eat crayfish from other habitats, but which do not frequent small ponds of this region. Examples are gars (*Lepisosteus spp.*), American Merganser (*Mergus merganser americanus*), and Hooded Merganser (*Lophodytes cucullatus*). The habitat choice serves, however, to increase vulnerability to some turtles which are common associates of *C. immunis* in these surroundings. General scarcity in situations other than that most preferred is probably responsible for the small number of individuals occurring in the food of vertebrates as well as for the fewness of vertebrates which are known to be their natural enemies.

Fishes. — In the food of the bowfin (*Amia calva*), *C. immunis* ranks third after *C. virilis* and *C. propinquus* among the crayfish

species preyed upon in southern Michigan (Lagler and Hubbs, 1940; Lagler and Applegate, 1942). The only other fish recorded as a predator of *C. immunis* is the smallmouth bass (*Micropterus d. dolomieu*), although it may safely be assumed that the largemouth bass (*Huro salmoides*) and other predacious fish species are numbered among its natural enemies.

Amphibians. — We have no records of predation on *C. immunis* by an amphibian, although frogs, toads, and mudpuppies are known to eat crayfish (Tack, 1941; Lagler and Goellner, 1941).

Reptiles. — Examinations of an extensive series of water snakes (*Natrix s. sipedon*) and garter snakes (*Thamnophis s. sirtalis*) from aquatic habitats have failed to disclose a relationship between ophidians and this species.

Owing to the somewhat less general abundance of *C. immunis* and to its more restricted habitat preference, it has fewer turtles among its natural enemies than other crayfishes have (Lagler, 1943). Only 21 specimens of *C. immunis* were found in 323 snappers (*Chelydra serpentina*), but not all of these turtles were from habitats frequented by this crustacean. It was the only one identified in the food of 27 geographic turtles (*Graptemys geographica*), mostly from the slow-moving portions of larger rivers in the southern part of the Lower Peninsula; seven were eaten. Nine of 22 crayfish in 15 spiny soft-shelled turtles (*Amyda s. spinifera*) were *C. immunis.*

Birds. — Marsh and wading birds, in addition to the Eastern Belted Kingfisher (*Megaceryle a. alcyon*), are this crayfish's principal avian enemies. Among the birds with definite records are the Great Blue Heron (*Ardea h. herodias*), Eastern Green Heron (*Butorides v. virescens*), and the American Bittern (*Botaurus l. lentiginosus*).

Mammals. — The otter (*Lutra c. canadensis*) feeds sparingly on *C. immunis* (Lagler and Ostenson, 1942). That the distribution of these two animals overlaps so slightly in the state and that the habitats of their principal choice differ so markedly probably accounts for the low incidence in the stomachs of otter.

Cambarus propinquus Girard

The most common crayfish in Michigan, found practically throughout the state, is *Cambarus propinquus.* It lives in a wide variety of lake, pond, and stream habitats, often in association with

C. virilis, and it is an outstanding component of the food of most animals that eat crayfish.

Fishes. — The longnose gar (*Lepisosteus osseus oxyurus*) is an unimportant predator of *C. propinquus* even as it was of *C. virilis*. Only one of each of these crayfish species was in the food of 136 of such gars from southern Michigan. Two hundred and four bowfins, however, had eaten a few more individuals of *C. propinquus* (a total of 75) than of *C. virilis* (a total of 67) (Lagler and Hubbs, 1940; Lagler and Applegate, 1942).

Rainbow trout (*Salmo gairdnerii irideus*) are prominent among the predators of *C. propinquus* in stream habitats. Creaser (1931) reports finding many specimens during stomach examinations of this trout from various localities in Michigan. We have additional records for 10- to 11-inch brook trout (*Salvelinus f. fontinalis*).

Amphibians. — The mudpuppy (*Necturus maculosus*) is the only amphibian predator of *C. propinquus* that we know (Lagler and Goellner, 1941). This crayfish occurred in 17 of 24 lake-dwelling mudpuppies that contained crayfish, and is probably also taken in larger streams that it shares with juvenile and adult mudpuppies.

Reptiles. — Crayfish-eating chelonians are among the most significant predators of this species (Lagler, 1943). Several members of *C. propinquus* were present in snapping turtles (*Chelydra serpentina*) from the Lower Peninsula, and 67 were found in 66 Blanding's turtles (*Emys blandingii*) from the same region. For Blanding's turtle there are almost twice as many records for *propinquus* as for *virilis*, which numbered 36. An intergrade between Bell's turtle and the Midwestern painted turtle (*Chrysemys picta: bellii* × *marginata*) from the Upper Peninsula was found to have eaten crayfish of the species *C. propinquus*, and one of 413 specimens of Midwestern painted turtles (*Chrysemys picta marginata*) from the Lower Peninsula had done likewise. Nine were in the food of 15 spiny softshelled turtles (*Amyda s. spinifera*) from southern Michigan. The species may also have been represented among the unidentifiable remains of many crayfish in 113 musk turtles (*Sternotherus odoratus*) and 27 geographic turtles (*Graptemys geographica*).

Birds. — American Mergansers (*Mergus merganser americanus*) eat crayfish of this species in both trout and nontrout waters, but fewer members of *C. propinquus* than of *C. virilis* are eaten by the Hooded Merganser (*Lophodytes cucullatus*). *C. propinquus* is con-

siderably more important, however, than *C. virilis* in the food of the American Golden-eye (*Bucephala clangula americana*). *C. propinquus* is second only to *C. immunis* in the food of the marsh-inhabiting American Bittern (*Botaurus l. lentiginosus*). Numerically it is approximately equal with *C. virilis* as a constituent in the diet of the Eastern Green Heron (*Butorides v. virescens*) and the Great Blue Heron (*Ardea h. herodias*). Many are also eaten by the Eastern Belted Kingfisher (*Megaceryle a. alcyon*).

Mammals. — Although probably of basic importance in the food of several mammals of this region, this crayfish is definitely known to be utilized only by the otter (*Lutra c. canadensis*) (Lagler and Ostenson, 1942).

Cambarus robustus Girard

Cambarus robustus occurs in scattered regions in the principal river systems of Michigan that drain into Lake Huron and Lake Erie and in the Grand River drainage. It characterizes the fauna of the swifter and shallower parts of watercourses and, like *C. virilis*, it seems to prefer streams with stones under which it may hide. The species is not very numerous, and hence its natural enemies are poorly known. There are no records among the Amphibia, Aves, or Mammalia.

Fishes. — One member of this species was found in a bowfin (*Amia calva*) of a sizable series studied by Lagler and Hubbs (1940), but none was present in specimens examined by Lagler and Applegate (1942).

Reptiles. — Among many crayfish eaten by snapping turtles (*Chelydra serpentina*) there was only one specimen of *C. robustus* (Lagler, 1943), but five of 22 crayfish in the food of 15 soft-shelled turtles (*Amyda s. spinifera*) were of this species.

Cambarus diogenes Girard

A preëminently burrowing species, *Cambarus diogenes* is known from widely separated areas throughout the state. During certain seasons it leaves its burrows and lives in lakes, ponds, and streams. Because of its secretive habits it does not appear to be a staple item in vertebrate fare, although it is eaten by several animals.

Fishes. — To date the northern pike (*Esox lucius*) is the only fish that has been shown to prey extensively (though locally) on *C. dio-*

genes. We have studied a large series of pike of all sizes from newly impounded waters over the old Seney marshes of the Upper Peninsula and have repeatedly found this crayfish in stomachs. It is eaten only sparingly by the bowfin (*Amia calva*) (Lagler and Applegate, 1942).

Reptiles. — Reptilian predators are confined to the turtles; we find the common snapping turtle (*Chelydra serpentina*) and intergrades between Bell's turtle and the Midwestern painted turtle (*Chrysemys picta: bellii* × *marginata*) preying to a small extent on this species (Lagler, 1943).

Birds. — *C. diogenes* was represented only once in several American Bittern (*Botaurus l. lentiginosus*), Eastern Green Heron (*Butorides v. virescens*), and Eastern Belted Kingfisher (*Megaceryle a. alcyon*) that have been found to prey on crayfish.

Mammals. — Again the only mammal for which we have a definite record of having eaten crayfish is the otter (*Lutra c. canadensis*), and in the series studied (Lagler and Ostenson, 1942) *C. diogenes* was identified only once.

GENERAL RELATIONSHIPS

Besides the specific records of predator–prey relationships of crayfishes that have just been given, there are many others that are at present grouped as general relationships. In part these are based on literature reports of "crayfishes" in the food of Michigan vertebrates, either in Michigan or elsewhere in their range. The rest are from analyses of stomach contents in which were found fragments of crayfish in such condition that identification of species was impossible. These general relations are yet to be explored for their species components in Michigan.

Fishes. — Among the fishes, most predacious forms feed to some extent on crayfish. The kinds included, besides those already mentioned in the species accounts, are: bullheads (*Ameiurus spp.*), mud pickerel (*Esox vermiculatus*), white bass (*Lepibema chrysops*), yellow perch (*Perca flavescens*), pikeperch and saugers (*Stizostedion spp.*), rainbow darter (*Poecilichthys c. caeruleus*), warmouth bass (*Chaenobryttus gulosus*), larger sunfishes (*Lepomis spp.*), crappies (*Pomoxis spp.*), northern rock bass (*Ambloplites r. rupestris*), and burbot (*Lota lota maculosa*).

Amphibians. — Crayfish in Michigan may be preyed upon by

amphibians other than the mudpuppy (*Necturus maculosus*), for which we have already given records. Frogs (*Rana catesbeiana, R. clamitans, R. pipiens,* and *R. palustris*) and the American toad (*Bufo americanus*) are known to eat crayfish elsewhere than in this state (Tack, 1941).

Reptiles. — In addition to the several species of turtles that are predators of these crustaceans we have one Michigan record each for the common water snake (*Natrix s. sipedon*) and for the queen snake (*Natrix septemvittata*).

Birds. — Many birds other than those already listed prey on crayfish. Prominent among these by their occurrence in Michigan are: Pied-billed Grebe (*Podilymbus p. podiceps*), American Egret (*Casmerodius albus egretta*), Snowy Egret (*Leucophoyx t. thula*), Little Blue Heron (*Florida c. caerulea*), Black-crowned Night Heron (*Nycticorax nycticorax hoactli*), Black Duck (*Anas rubripes*), Pintail (*Anas acuta tzitzihoa*), Blue-winged Teal (*Anas discors*), Shoveller (*Spatula clypeata*), Lesser Scaup Duck (*Nyroca affinis*), Buffle-head (*Bucephala albeola*), Old Squaw (*Clangula hyemalis*), White-winged Scoter (*Melanitta fusca deglandi*), Ruddy Duck (*Oxyura jamaicensis rubida*), Red-breasted Merganser (*Mergus serrator*), Eastern Red-tailed Hawk (*Buteo jamaicensis borealis*), Northern Red-shouldered Hawk (*Buteo l. lineatus*), American Rough-legged Hawk (*Buteo lagopus s.-johannis*), Broad-winged Hawk (*Buteo p. platypterus*), Marsh Hawk (*Circus cyaneus hudsonius*), Eastern Pigeon Hawk (*Falco c. columbarius*), Sandhill Crane (*Grus canadensis tabida*), King Rail (*Rallus e. elegans*), Virginia Rail (*Rallus l. limicola*), Killdeer (*Charadius v. vociferus*), Ring-billed Gull (*Larus delawarensis*), Barn Owl (*Tyto alba pratincola*), Eastern Screech Owl (*Otus asio naevius*), Great Horned Owl (*Bubo v. virginianus*), and Northern Barred Owl (*Strix v. varia*).

Mammals. — Besides the otter (*Lutra c. canadensis*), already mentioned, other valuable Michigan fur bearers are natural enemies of crayfish. Dearborn (1932) has shown that these crustaceans compose a substantial amount of the food of the opossum (*Didelphis v. virginiana*), the raccoon (*Procyon l. lotor*), and the mink (*Mustela vison*). An interesting seasonal variation was noted for the mink; crayfish comprised 68 per cent of the bulk of its food in the summer and only 8 per cent in the winter. Errington (1941) has found that the muskrat (*Ondatra zibethica*) eats crayfish.

Although crayfish are eaten by man in some parts of the country, the practice is not common. Some crayfish are used as bait, however, by fishermen and by others as food for fishes being artificially propagated.

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ANGLERS' CATCHES FROM PORTIONS OF CERTAIN MICHIGAN TROUT STREAMS IN 1939 AND 1940, WITH A DISCUSSION OF INDICES TO ANGLING QUALITY *

DAVID S. SHETTER

IN MOST fish-yield studies so far reported it has been impossible to calculate the catch in pounds per unit of effort or per unit of water area because the fish removed by angling were not weighed. There were two good reasons for omitting the weighing: (1) Many of the early creel censuses were made by relief labor, which could not always be depended upon to take accurate measurements; hence the simpler the data requested the more reliable would be the information obtained; (2) At lakes particularly a large number of anglers leave the water at noon and at dusk. Creel-census clerks were required to record only the number of fish taken, the species, and an estimate of the average size of the catch. Unless the data to be written down were kept at a minimum, the census taker could not interview all the fishermen.

In 1939 and 1940 crews of the Civilian Conservation Corps were provided by state or United States Forest Service camps. These men were carefully selected and trained in their duties in advance of the fishing seasons. Where this help was not available, creel-census clerks were hired by the Conservation Department. All the work was carefully supervised. Intensive censuses of this type were limited to portions of seven trout streams in 1939 and to five in 1940, from one to twelve miles in length. Enough men were used to enable them to obtain all the information required without inconveniencing the anglers.

Delay in arrival of balances prevented weighing the catches until June 15, 1939, after which weights were secured with few exceptions.

* Contribution from the Institute for Fisheries Research of the Michigan Department of Conservation.

Prior to that date nearly all the fish were measured individually. On all streams there were times when weights could not be recorded because fishermen disregarded the signs asking them not to clean their fish before they had been weighed. Rarely were anglers seen without being interviewed by the clerks. The probable catch of these anglers was assumed to be average for the two-week period.

In order to make the final figures on yield as complete and as accurate as possible the following procedure was employed. Weight–length curves for each species and for each stream were prepared from all fish that were weighed and measured. From these curves the weights of fish of known lengths could be closely approximated. If only the number of fish caught by an angler was known, the average length for each species for the period was used, and the corresponding weights on the curves were assigned to this catch. The catch of anglers seen but not questioned was considered average in all respects for the period and was also added to the known total.

Errors in the calculated yields may be present because of inaccurate measurements of the fish, variation in the weight–length relationship of trout during the fishing season, and dependence on the catch of anglers not interviewed. However, they are to some extent compensating and were present on each stream, so that results should be reasonably accurate and comparable.

Areal measurements of the portions of streams under census were determined either from plane-table maps or by chaining the length and width.

YIELD TO THE ANGLERS

Tarzwell (1938) reported the yield of rainbow trout in Tonto and Horton creeks, Arizona, as from 29.5 to 54.2 pounds per acre in 1936 and 1937, with an angling pressure ranging from 125 to 241 man-hours per acre per season. What part of the catch consisted of hatchery trout is not stated, but some planting was done in both streams, possibly with legal-sized fish. In determining the natural production of a stream the weight of planted hatchery trout caught should be deducted from the total poundage recorded. Tarzwell's figures may therefore be too high.

From data published by Surber (1940) it may be calculated that the yields of brook and rainbow trout per acre in 1938 and 1939 in the St. Mary River, Virginia, were 7.55 and 9.64 pounds, respectively.

DATA FOR THE 1939 AND 1940 SEASONS ON PORTIONS OF MICHIGAN TROUT STREAMS COVERED BY INTENSIVE CREEL CENSUSES

Stream and county	Water area in acres	Total hours of angling	Angling hours per acre per season	Number of legal trout caught	Total pounds of legal trout removed	Number of legal trout caught per hour	Pounds of legal trout caught per hour	Pounds of legal trout caught per acre	Net yield * per acre	Percentage of unsuccessful anglers
1939										
Pine River (Lake)	57.5	15,226.50	265	7,459	1,517.71	0.49	0.100	26.4	23.1†	48
Pigeon River (Otsego)	65.4	6,754.75	103	3,213	725.38	0.48	0.107	11.1	?‡	56
North Branch of Au Sable River (Crawford)	54.5	7,050.00	129	2,914	673.06	0.41	0.095	12.3	11.6†	63
Little Manistee River (Lake)	17.7	2,333.25	132	862	249.51	0.37	0.107	14.1	11.4†	59
Canada Creek (Presque Isle)	21.2	873.00	41	278	67.64	0.32	0.078	3.2	?	57
White River (Newaygo)	10.4	3,080.00	296	1,853	318.11	0.60	0.103	30.6	?	41
Hunt Creek (Montmorency)	4.3	780.50	175	492	66.98	0.63	0.086	15.6	?	55
1940										
North Branch of Au Sable River (Crawford)	54.5	6,675.50	123	2,128	574.30	0.33	0.086	10.6	9.6§	63
White River (Newaygo)	17.5	2,131.75	122	448	148.50	0.22	0.070	8.5	7.5§	79
East Branch of Tahquamenon River (Chippewa)	6.3	725.00	115	689	172.70	1.02	0.238	27.4	22.7†	41
Fishdam River (Delta)	3.0	589.50	197	471	204.90	0.80	0.348	68.3	64.7§	42
Hunt Creek (Montmorency)	4.6	901.25	189	406	60.35	0.45	0.067	12.8	12.8†	66

* Total poundage minus weight of catch of legal-sized hatchery plantings.
† All legal-sized hatchery plantings were marked.
‡ Estimates impossible because not all legal-sized hatchery plantings were marked.
§ Based on percentage of legal-sized hatchery plantings taken in preceding years.

Angling pressures ranged from 103 to 130 man-hours per acre per season. Hatchery fish were planted as advanced fingerlings from 3.75 to 6.00 inches in length during late summer and fall in the years 1935, 1936, and 1938. Since they were in the stream at least one year before entering the catch their contribution to the poundage produced may be regarded as production by the stream.

In 1939 the total yield from sections of seven Michigan trout streams was 15.7 pounds per acre (Table I). Considerable variation is evident. The highest yield in pounds per acre of trout was from the White River (30.6), followed in order by the Pine River (26.4), Hunt Creek (15.6), the Little Manistee River (14.1), the North Branch of the Au Sable River (12.3), the Pigeon River (11.1), and Canada Creek (3.2).

In 1940 sections of only five streams were covered by intensive creel censuses because of a reduction of Civilian Conservation Corps manpower. The total yield from them was 15.3 pounds per acre, but yields of legal trout per acre varied greatly in different waters. The highest yield was recorded for the Fishdam River (68.3), followed by the East Branch of the Tahquamenon River (27.4), Hunt Creek (12.8), the North Branch of the Au Sable (10.6), and the White River (8.5). The marked difference in the yield recorded for the White River in 1939 and 1940 demonstrates the great variation between a stream area that is a good trout habitat during the entire year and one which is capable of supporting trout only during spring and early summer.

Calculations of the yield of "wild" trout (net yield) were possible because all hatchery-reared trout present in the areas under census were either jaw-tagged or fin-clipped or the percentage of hatchery fish in the catch could be estimated on the basis of returns from previous plantings of marked trout on many of these streams (Shetter and Hazzard, 1942). From the available data concerning the pounds per acre of wild trout removed by angling it may be computed that from 80.5 to 94.8 per cent of the total poundage so removed was composed of trout of natural origin, even though generous plantings of legal-sized fish were made.

INDICES TO ANGLING QUALITY

Two indices for comparing angling quality are presented below and in Table I. One index, which has been widely used in the past,

is the number of legal trout caught per hour; the other is the number of pounds of legal trout caught per hour. After trials in computing several other indices to angling quality, such as the percentage of successful anglers, size of trout, and so on, the simplest and most accurate measure appears to be the number of pounds of legal trout caught per hour of angling. This figure includes the factors of number and size of fish, which are generally considered equally important in determining the quality of angling.

Depending on which criterion is used to judge the creel census data, the streams will change their position in the listings of angling quality. This is illustrated by Table II.

TABLE II

RATINGS OF STREAMS BASED ON THE NUMBER AND ON THE POUNDS OF TROUT CAUGHT PER HOUR IN 1939 AND 1940

	Judged on the basis of number per hour		*Judged on the basis of pounds per hour*	
1939	Hunt Creek	(0.63)	Little Manistee River	(0.107)
	White River	(0.60)	Pigeon River	(0.107)
	Pine River	(0.49)	White River	(0.103)
	Pigeon River	(0.48)	Pine River	(0.100)
	North Branch of Au Sable River	(0.41)	North Branch of Au Sable River	(0.095)
	Little Manistee River	(0.37)	Hunt Creek	(0.086)
	Canada Creek	(0.32)	Canada Creek	(0.078)
1940	East Branch of Tahquamenon River	(1.02)	Fishdam River	(0.348)
	Fishdam River	(0.80)	East Branch of Tahquamenon River	(0.238)
	Hunt Creek	(0.45)	North Branch of Au Sable River	(0.086)
	North Branch of Au Sable River	(0.33)	White River	(0.070)
	White River	(0.22)	Hunt Creek	(0.067)

It should be pointed out that the average sizes of the trout caught in the various streams contributed noticeably to their order in the lists. In Table III will be found the average lengths and the average weights of the various species of trout captured in the creel-census areas in 1939 and 1940. Where there are no entries in the table, the species were not present in the streams specified or were not captured by anglers. If the ratings of the streams on the basis of pounds of trout captured per hour of angling are compared with the other available creel-census data and the average sizes given in the table,

TABLE III

AVERAGE LENGTHS AND AVERAGE WEIGHTS OF TROUT TAKEN BY ANGLING FROM PORTIONS OF MICHIGAN TROUT STREAMS COVERED BY INTENSIVE CREEL CENSUSES DURING THE 1939 AND 1940 TROUT SEASONS (LENGTHS IN INCHES, WEIGHTS IN OUNCES)

Stream and year	Brook trout			Brown trout			Rainbow trout			All trout	
	Number	Average length	Average weight	Number	Average length	Average weight	Number	Average length	Average weight	Number	Average weight
1939											
Pine River	1,446	7.9	2.97	12	8.9	5.33	6,001	8.3	3.32	7,459	3.26
Pigeon River	2,337	8.1	3.29	228	9.1	5.13	648	9.0	4.24	3,213	3.61
North Branch of Au Sable River	2,430	7.8	2.83	464	10.5	8.04	20	9.5	7.80	2,914	3.69
Little Manistee River	273	8.7	4.66	254	9.5	5.02	335	8.2	4.32	862	4.63
Canada Creek	265	8.4	3.86	2	7.2	2.15	11	7.3	5.02	278	3.89
White River	1,853	7.8	2.75	...	...	...	...	...	...	1,853	2.75
Hunt Creek	492	7.5	2.18	...	...	...	...	...	...	492	2.18
1940											
North Branch of Au Sable River	1,759	8.9	3.16	355	11.1	10.00	14	9.1	6.17	2,128	4.32
White River	143	8.3	4.21	141	9.5	6.01	164	9.5	5.65	448	5.30
Fishdam River	446	9.1	6.76	25	11.0	10.56	...	...	...	471	6.96
East Branch of Tahquamenon River	689	8.5	4.01	...	...	...	...	...	...	689	4.01
Hunt Creek	406	7.6	2.38	...	...	...	...	...	...	406	2.38

it will be seen that, in order to arrive at a high pounds-per-hour index, either a large number of trout must be taken per unit of effort or the size of the trout caught must be above average. Examination of the tabular material reveals a marked variation between Hunt Creek and the Little Manistee River in 1939. On Hunt Creek the highest catch per hour (0.63 fish) was recorded, yet the fish were of the least average weight (2.18 ounces), and the calculation of the pounds-per-hour index placed it second from the bottom (0.086) when quality of angling was judged on the latter basis. On the Little Manistee River the catch per hour was only 0.37 fish, yet the average size of all trout caught was over twice that of fish caught in Hunt Creek, and the calculation of the pounds-per-hour index was increased accordingly (0.107) and more nearly to the true position as regards general angling quality.

It is the author's belief that the pounds of fish caught per unit of angling effort is the more valid index in comparing the quality of the angling of different bodies of water or in comparing the results of the angling in different seasons or parts of the season on the same body of water, and this index will be employed in the future whenever it is possible to obtain the weight of anglers' catches.

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